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Workspace Design Handbook for Standardized Command Posts

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U.S. Army Research Institute for the Behavioral and Social Sciences

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This handbook was developed for use in the Army Chief of Staff's Standardized Command 'ost program. It provides recommended design techniques, assessment approaches, sample perational considerations, human factors guidelines, and implementation advice for the design f Army tactical command posts. All information in the handbook is based on subject matter xperts' knowledge of human factors design and soldier performance. The handbook discusses perational considerations in terms of standardization and establishment of operational equirements for workspace design. It also points out the need to go beyond arranging quipment in command post design and describes how to incorporate the soldiers and their issions in design. Keywords: Command and Control systems, Human factors engineering, ... Workspace ...

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Workspace Design Handbook for Standardized Command Posts

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FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Leavenworth Field Unit conducts an extensive program of research on soldier performance in command and control (C2). The Field Unit's research accomplishments include a successful track record of resolving critical behavioral concerns that occur because of the introduction of automation into command posts. This research supports the development of a tactical C2 system that can be fully integrated into command post operations and that helps the soldiers in the performance of their tasks.

The Director of C2, Combined Arms Combat Developments Activity (CACDA), obtained ARI's assistance with the Standardized Command Post project when it was resumed during the summer of 1989. The role of the ARI Fort Leavenworth Field Unit was to serve as a consultant on human performance matters in the redesign of battalion through corps command posts and in the design of future command posts to be equipped with emerging tactical communications and computers. These responsibilities were established in the Standard Command Post Letter of Instruction 1-89, dated 29 June 1989, from the Doctrine and Training Branch of C2, CACDA. The ARI work was performed under the memorandum of agreement between CACDA and ARI entitled "Development and Implementation of the Future Battle Laboratory," dated 30 June 1989. This handbook was coordinated with the Director of C2, CACDA, and Chief of the Standardized Command Post (SCP) project. An earlier version of the handbook was provided to the sponsors for use as ARI Working Paper LVN-90-01 during March 1990.

The need for consistent guidance to address the needs of the soldiers in design became evident after several versions of SCP designs were developed and presented for review. In February of 1990, ARI offered to develop a set of workspace guidelines for CACDA based on manpower, personnel, human factors, and safety design criteria. This handbook represents the compilation of design guidelines to be used by the SCP combat developers for the future command post designs. This handbook reflects the assistance of many individuals and agencies; most notably the assistance provided by the U.S. Army Human Engineering Laboratory and the MANPRINT office at the Natick Research, Development, and Engineering Center.

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Other individuals contributed by providing information and references. These included Mr. Steve Beaudoin, Standardized Integrated Command Post System (SICPS), RD&E Center; Mr. Richard Brown, SICPS, CACDA; Dr. James Geddie, HEL; Mr. Dave Gibson, Secure Lighting Office, Communications-Electronics Command (CECOM); Mr. Mike Gravelle and Mr. J. N. Hecht, Crew Systems Ergonomics Information Analysis Center (CSERIAC); and CPT Dave Jackson, Maneuver Control System, CACDA.

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WORKSPACE DESIGN HANDBOOK FOR STANDARDIZED COMMAND POSTS

1. INTRODUCTION

The Standardized Command Post (SCP) program is an initiative to provide guidance to document doctrinal functions, arrangement of shelters, shelter workspace, equipment, and personnel. While the equipment and personnel authorizations have been standard in the sense of Tables of Organization and Equipment (TOE), operational usage has been very different from one organization to another. The design of the SCP will be a dynamic process combining the shelters and equipment to support the required personnel in performance of mission essential functions. Workspace layout combines these design elements together into an effective system. Designs of the past have considered the equipment, but they have not always been optimized for effective, efficient, and safe operation by soldiers. **Soldiers and what they have to do to accomplish their mission are paramount in the development of SCP.**

This handbook has been put together for combat developers at Training and Doctrine Command (TRADOC) proponent centers and schools who hold the responsibility for planning SCP and implementing the SCP concepts in doctrine and institutional training. SCP is not a typical Army design effort because it is not rooted in the established requirements processes and acquisition procedures. Since the combat developer is performing a unique role in the SCP program and will not be familiar with the full range of design requirements, this handbook provides tailored guidelines for soldier considerations. The handbook should also serve as a useful reference for materiel integrators and human factors practitioners who support the SCP program. **The general premise of this handbook is that soldier considerations must be solidly integrated into the workspace design process, rather than only designing for shelters and equipment and assuming that the soldiers' needs will be met or that soldiers will adapt to the environment.**

Workspace layout is not a new problem. It has been wrestled with by many in the industrial community, as well as the Army, under the term **human factors**. The SCP designer should know about the implications of these factors, and they should design using standard and accepted procedures for addressing soldier considerations. This handbook identifies procedures and guidelines to ensure SCP designs that facilitate effective performance. Guidelines are provided that have been taken from military standards and handbooks and other industrial and Army literature. Examples are given on how to tailor and put these guidelines into practice. This handbook alone will not make a combat developer into a seasoned practitioner of human factors design. Its main purpose is to introduce design techniques and soldier equipment interface guidelines. This handbook lays out a general procedure for SCP design and highlights critical soldier

considerations to use in integrating existing materiel and shelter components.

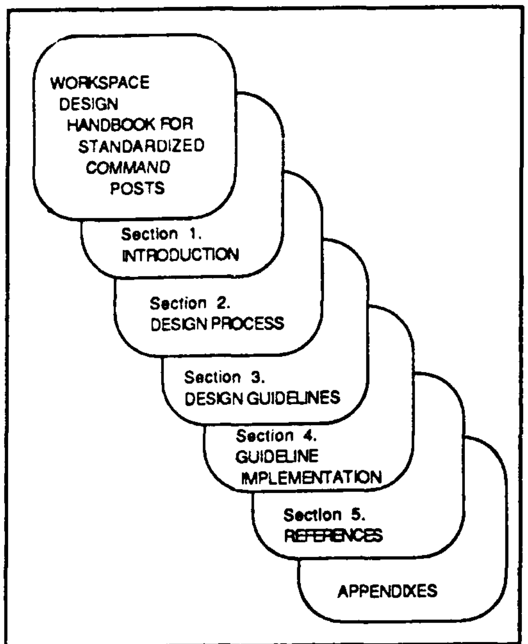


Figure 1. Organization of this Handbook.

The handbook is divided into five sections and three Appendixes as presented in Figure 1. Section 1 addresses the background and rationale for these guidelines. Section 2 recommends a process to follow for SCP design. It addresses the importance of specifying operational constraints and goals. Also Section 2 describes analysis techniques necessary for appropriate workspace design and approaches for assessment of the designs. General and detailed guidelines are presented in Section 3. Section 4 presents a summary of design considerations and examples of tailoring the guidelines. Section 5 includes the references that are recommended to obtain more information.

Link analysis is one of the procedures described in Section 2. The goal of link analysis is to economize the movement of personnel, information, and products. The groupings of equipment and personnel are examined to optimize the links among them. Link analysis will help determine the best functional groupings of staff elements and the most efficient layouts of workspace. Less movement of staff and information translates to faster and more efficient command post operations, which in turn will lead to effective performance.

Above all else, the workspace must be designed so that effective performance is achieved.

The basis for the guidelines contained in Section 3 follows this same premise. In order to perform effectively, command post personnel need to have sufficient room to move around and interact with fellow staff. They need furnishings that provide the proper features and dimensions. When computer workstations are incorporated into the command post, precautions need to be taken to prevent operator fatigue. Also the staff must be able to access and view all displays. The command post environment must be designed for safety and to provide adequate lighting and temperature. Performance over prolonged, stressful periods of command post operation must be supported by optimizing the

functionality of the workspace. These examples represent some of the guidelines that are covered in this handbook.

With this handbook the designer should produce a more efficient and effective command post because a conscious effort will have been made to design to fully integrate the soldier. By applying the presented techniques and detailed guidelines that have proven their usefulness in industrial and Army design alike, the designers can increase their confidence that an effective system will be produced.

2. DESIGN PROCESS

Operational Considerations

A command post, just like command and control, does not exist for its own sake. It is there to support the commander and his staff in commanding a force to win a battle. This context is not likely to be forgotten in the design of the command post. But because this relationship is so obvious, the specification of the operational requirements may be overlooked.

The operational goals and constraints of the command post organization must be carefully identified to provide the proper framework for command post design.

The following paragraphs discuss ten different issues that are being referred to in this handbook as operational considerations. The result of considering these operational factors will be the specification of required capabilities of the command post. These issues need to be addressed and policy decisions made about the way a command post will operate. These decisions are important so that designers, developers, and users understand how the command post will be employed and in what environments. These considerations have direct impact on designing for the soldier.

Operational environments. The operational environments should be specified in which the command post must function along with the relative expected priority of each. The operational and organizational (O&O) concept and required operational characteristics (ROC) for the Army Tactical Command and Control System and individual battlefield functional area systems are sources for this information. Excerpts on the operational and organizational modes from the Army Command and Control System employment concept are provided at Appendix A. For example, the normal missions of an armored division include desert and winter warfare, while assignments to jungle and mountain warfare are of low probability. The guidelines in Section 3 provide examples of environmental parameters that need to be considered for maintaining an adequate and safe environment for soldiers.

Nuclear, biological, and chemical (NBC) warfare is a normal operating environment that all tactical forces must be prepared for. Operations in potential NBC environments require special design forethought. The designer will need to know whether the command post will sustain operations in an NBC environment or whether they will withdraw once NBC conditions are present. For sustained operations, there may be additional requirements on the command post design to provide for over pressure, an entry vestibule, storage of extra military operations protective posture (MOPP) clothing, and extra drinking water. If the set policy will be to withdraw from a threatened area, then having

appropriate monitoring equipment and warning procedures increase in importance, as well as the time lines for tear-down and displacement.

Detectability. Limiting detection by disciplining light, noise, and other emissions is a key operational concern. Lighting requirements are based on the capabilities of night vision devices to detect low energy sources in the visible and near infrared spectrum. Expected command post locations on the battlefield needs to be taken into account to determine the level of precaution necessary for lighting and noise discipline. Guidelines for secure lighting and aural nondetection are included in Section 3.

Dispersion. Dispersed command post operations is one of the primary drivers for SCP. The design needs to recognize the doctrinal parameters of achieving dispersion. Specifically, the parameters to be identified for each command post are: minimum and maximum distances among command posts, frequency of relocation, and percentage of TOE moved in one segment using organic vehicles. Minimum distances establish the safe distance for locating one command post next to another. Maximum distances establish the extent to which command posts can be located in order to maintain contact with one another and with their subordinate forces.

Redesign of command posts allows an increase in the application of principles of battlefield survivability. That is, it reduces the likelihood of detection by decreasing physical signatures and designation by using consistent site layouts from one command post to another. Smaller command post sizes and improved vehicles increase the mobility of command posts. A dispersed concept also allows the separation of emitters. The smaller physical size of command post cells better supports the goal of "blending" into the existing environment; by locating within factories, warehouses, and other buildings. Smaller, more numerous command post cells will supply the personnel and equipment capabilities for redundancy of functions, which also will increase the chances for survivability of command. Dispersion will be possible because of the emerging capabilities for computer-supported cooperative work (CSCW), also known as shareware or groupware. This "electronic collocation" counters some of the disadvantages of separating staff.

Increased dispersion creates new challenges for soldier performance areas like communications and staff interaction. Dispersion is not without disadvantages. For example, there will be added costs because equipment cannot be shared as much. Requirements for generators, computers, test equipment, tool kits, shelters, life support activities, and site security will

increase when functions and staff elements are more widely dispersed. But it is critical for survivability to disperse.

Back-ups. Back-up capabilities also need to be considered for dispersed command posts. One advantage of the dispersed command post concept is that one command post element can assume the duties when other elements relocate. The workspace design should accommodate these alternative operating modes. Also similar considerations for back-up capabilities apply under "graceful degradation" to sustain command and control when personnel and equipment are lost. Special considerations need to be made for procedures, spare equipment, and associated workspace requirements in the event of tactical computer failures.

Operation-on-the-move. Operation-on-the-move is a possible tactical consideration. The designer should identify what the requirement is, if any, to operate some cell or staff element while moving. This is especially important for operating tactical computers and communications. For example, operation-on-the-move impacts workspace design by requiring secure, safe seating (e.g., with a five point harness) for computer operators and locating necessary equipment within the reach of the seated operator.

Continuous operations. Continuous operations have an impact on manpower requirements and scheduling of duty shifts. The effects of sleep deprivation are well documented and its effects are particularly menacing for command and control operations.

> Cognitive performance is more sensitive to the effects of brief, fragmented or no sleep than physical strength and endurance. So those elements of military operations involving cognitive abilities will be more affected. Cognitive abilities are the weak link in human performance in CONOPS. Six to eight hours of sleep each night will maintain cognitive performance indefinitely. Three to four hours sleep each night will maintain cognitive performance for 5-6 days. Less than 3 hours sleep each night will lead to rapid declines in cognitive performance and hence military effectiveness. Soldiers can remain militarily effective for only 2-3 days with little or no sleep. (p. 1-17, Belenky, Krueger, Balkin, Headley, & Solick, 1987)

The limits of waking hours without rest are likely to be lower for the older soldier.

These well-established findings on sleep loss have particularly important implications for maintaining adequate manpower for dual duty shifts and for providing adequate "life support" considerations.

> Sleep deprivation results in . . . decreased capacity for sustained selective attention, and therefore a diminished capacity for efficient performance of higher level cognitive tasks (Kjellberg, 1977). **Performance on cognitive tasks requiring calculations, creativity, and the ability to 'plan ahead' effectively are especially sensitive to sleep loss. . .** .The implications of these studies are particularly important for command and control personnel because the abilities that enable soldiers at all levels of command and control to respond quickly and effectively to constantly changing battlefield conditions -- abilities to quickly anticipate, recognize, and correct areas of weakness in their own defenses, as well as to anticipate, recognize, and take advantage of opportunities to seize the initiative from attacking forces -- are the abilities that will be degraded by sleep loss. (p. 1-2, Belenky, Krueger, Balkin, Headley, & Solick, 1987)

Set-up and tear-down. The ease and speed of set-up, tear-down, and time in transit for command post units are also operational considerations. These constraints increase in importance as the frequency of moves increases and the need for rapid set-up/tear-down increases. (*Appendix A identifies representative mobility characteristics of command posts.*) One outcome of down-sizing command posts and shelters is the associated reduction in the number of soldiers per command post. With fewer soldiers, it may be difficult to reach the required minimum for fast and safe set-up for tasks requiring simultaneous actions, (for example, tent set-up requiring at least three soldiers or lift requirements of heavy equipment).

Shelter arrangement. The arrangement of shelters can have an affect on the sequence and speed of the set up operation. For example, placing M577s side-by-side can speed up the set-up of extensions, because they can be set up simultaneously without surveying distances. When M577s are arranged end-to-end or perpendicular, the first M577 needs to be positioned and the extension set up started before the next M577 can be positioned and its extension set up.

Arrangement also affects the shape of the workspace. Some shelters can be joined together to create a large common work area, or they can be arranged to make small, separate working compartments. Typically in command posts, arrangements are desired that do both. Careful design considerations will need to be given to meet both criteria and to obtain rapid set-up and tear-down.

Equipment off-loading. Another consideration is the off-loading of equipment for operation. For example, the VFMED (Variable Format Message Device) is supported by a vehicular mount in an M577. The TCT (Tactical Computer Terminal) can be mounted in the M577 or down loaded for operation in a tent. For example, set-up time would be less if a computer is left in its M577 carrier for operation. But if an extra soldier is needed to carry message traffic back and forth between the M577 tent extension and the computer during operations, then there may be an overall loss in efficiency and added manpower requirements. In expansible vans, MCS (Maneuver Control System) computers can be placed over the main body of the platform rather than over the outriggers to save set-up time and to better centralize weight distribution. However, locating all fixed equipment near the center line of the van also places considerable limitations on possible workspace arrangements. The designer may come up with a good static "load plan," but one that does not support the dynamic operations and movement of the staff. There will surely be trade-offs between speed of emplacement (and weight/bulk of equipment) and having the equipment in the best location to support the essential functions.

Classified information. Operational considerations need to be given to the requirements for restricting classified information from unauthorized personnel. With the tendency toward smaller command posts there may not be enough personnel or space to allow the proper procedures for dealing with classified information. The designer should be sure that enough personnel with the appropriate clearances and training are identified and that adequate workspace considerations are made.

Operational Summary

This discussion of operational constraints is not exhaustive of the factors to be used in design. This initial list is provided to give some indication of how soldier performance issues and operational considerations go hand-in-hand to impact design. The operational considerations do need to be articulated by the designer as statements of goals and constraints that impact the design process. Also these considerations provide the basis for explaining why command posts are structured as they are and will be useful to understand the design background as circumstances require changes and improvements. Most importantly, they provide the "mark on the wall" to set requirements for the design process and to use in trade-offs between conflicting constraints.

Analysis in Design

There are two levels of design that should be considered. First is the organizational perspective: looking at the groupings and locations of functional command posts and cells. The second is the detailed workspace layout. Alternative locations for staff elements and groupings of staff within a location makes up the organizational level of design. Specification of functions and detailed tasks should be performed for organizational design to determine the groupings of functions before the more detailed process of manning and workspace layout are considered. There should be iteration between the two levels. Issues will come up at the shelter level that will require larger organizational changes.

Overview of design techniques. The functions of command and control must be articulated in such a way that in analysis, design, and evaluation there will be enough information to make logical trade-offs and decisions. A **functional analysis** is the technique to decompose the overall mission of a command organization in successive levels of detail to produce a detailed description of the jobs, tasks, and processes. A **manpower analysis** will provide an estimate of the quantities of personnel needed to perform the functions. The closely related **workload analysis** will help identify the level of effort that is required of the soldiers to perform the various functions. It should help to identify excessive levels of workload as well as those positions that have spare capacity for taking over some of the excessive workload. With the functions and personnel identified, one can develop the required list of equipment and perform a **link analysis**. The **link analysis** will produce the strength of interrelationships among the multiple soldiers and elements making up the command organization. It is also used to determine the good locations and most important communications among elements to use in **workspace design**. During the design process and after, **design assessment** is important to be sure that the more important design goals are not overtaken by minor goals or constraints. Repeated evaluations using prototypes can help test design and performance assumptions. Throughout design it is important to follow good **design management** procedures. The relationship of these analysis, assessment, and management guidelines are illustrated in Figure 2.

It must be pointed out that what is recommended here is a series of analyses, that is a sequence where the output of one analysis would feed later analyses. However, the analyses cannot be treated only as a sequential process. Each of the techniques benefits from the outputs of the others. Each requires a set of inputs or at least assumptions from the others. The designer will need to work through these interrelationships.

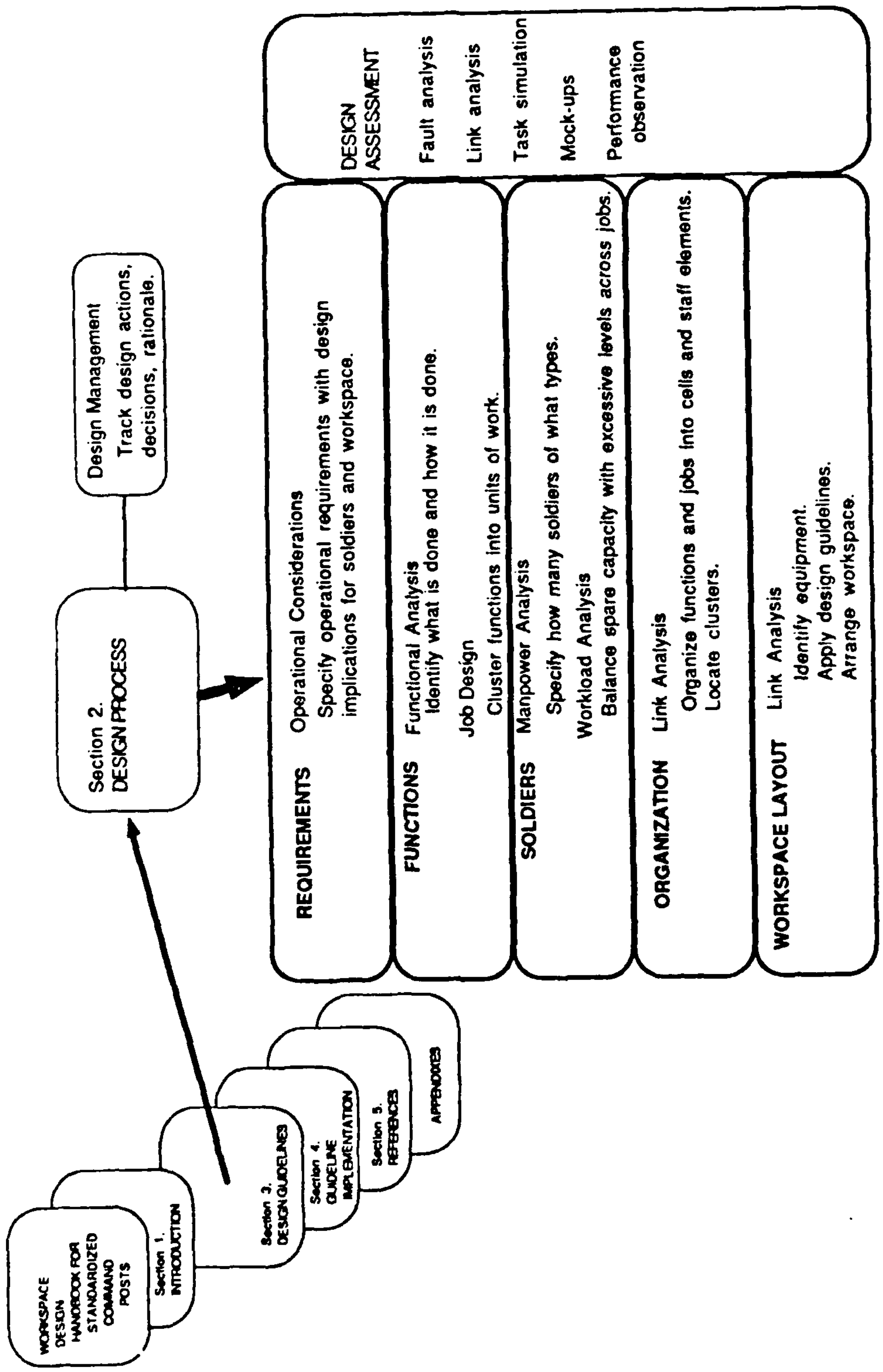


Figure 2. Workspace design process.

Functional analysis. Functional and task analysis are the basic tools of industrial engineering and human factors. (Note that most distinctions between functions and tasks are fairly arbitrary with the difference primarily being the level of detail on the task. Functional analysis and task analysis will be used interchangeably in this discussion.) These methods, first developed by industrial engineers for designing efficient processes for assembly processes, are commonly applied to a wide range of human factors applications. The methods should be used to sort out and articulate what tactical command posts do and how they do it. In order to design efficient workspaces, the tasks and relationships among them must be thoroughly understood.

Command posts can be viewed as organizations for processing information to make timely decisions. In command posts, like factories and offices, processes merge specialties together and are characterized by information flow. Functional analysis is used to describe these processes and the corresponding information flows. Functional analysis can be documented using various approaches. The important aspect of functional analysis is that it provides a method to break down the processes of an organization into elements for analysis. At the proper level, sufficient detail is available to use for many design actions.

Design of command post operations and facilities is particularly complex because of the interaction among components and the uncertainty inherent in battlefield operations (for example, intent and actions of opponent, status of own forces, unknown timing, uncertainty regarding future events). Also the organizational groupings of command posts are complex. The organizational and functional adaptability which staffs must have to respond to special battlefield requirements adds to the complexity for the designer. These dynamic requirements account for large variations in what tasks are performed, how they are performed, how often they are performed, and by whom. Because of the complexity and variation it is important to break down processes to a very detailed level. It is important to recognize the variability in how functions are performed and to define or incorporate existing standards for the quality of task performance that needs to be maintained. Both standards and variability should be assessed to determine the impact on alternate design concepts.

Functional analysis of command post operations should produce a set of information to be used in design. An example set of information categories and a format for a single function is presented (based in part on draft MIL-STD-1478; Myers, Tijerina & Geddie, 1987).

Function name:
Information required:
Actions, operations, decisions:
Knowledge, skill requirements:
Simultaneous tasks:
Coordination with others:
Number of personnel:
Product produced:
Action or product descriptors Criticality: Frequency: Accuracy: Work rate: Time to complete:
Location (staff element):

This information will be used to address personnel, manpower, organizational, and workspace needs. For example, the required actions, knowledge, and skills help define the personnel requirements; frequency, criticality, coordination, and simultaneous tasks help determine the required manpower levels; and so forth. All of the functional information categories impact on workspace design.

All man-loading tasks need to be specified or the designer runs the risk of not designing for enough people and workspace. The priority and frequency of functions will be two primary criteria in determining the location of functions and the individuals who perform those functions.

Task analyses should be done as a partnership between subject matter experts (doctrinal authors, trainers, and practitioners) and job designers (human factors specialists, industrial or behavioral psychologists). Though this analysis may seem to be overwhelming, many good sources exist that serve as starting points to identify functions and tasks. These include field manuals like FM 101-5, training manuals like ARTEP 100-15 MTP, and system descriptions like Magnavox (1988) produced for the Army Tactical Command and Control System (ATCCS). Technical literature is another good source of information. Carter, Archer, and Murray (1988) provide functional flows and descriptions of division-level staff operations. Bean, Ottenberg, and Mukherjee (1983) provide functional flow descriptions for battalion through corps echelons. Scheiber, Bryden, Hargis, and Maggelet (1986) produced functional flows for similar allied operations. Comprehensive information and product flows for the corps, division, and brigade Force Level Control System (FLCS) should be very useful (Command and Control, 1990). A comprehensive task analysis on higher echelon staff operations is reported by Modisette, Michel, and Stevens (1978). These last two references probably best represent the intent and information

that SCP designers should try to emulate.

Job design. Job design is one way to structure how the organization gets done what is required. In job design the required functions and tasks are taken and clustered into units of work for people. These units of work are called jobs. Some general guidelines for job design are listed in the following box.

> Tasks assigned to one job should require similar and related knowledge and information.
>
> Tasks assigned to a given job should be done in the same location.
>
> Tasks closely related in function or in time should be assigned to one job.
>
> Tasks assigned to a given job should relate to the same equipment or subsystem. (p. 68, Chapanis, 1977)

Manpower analysis. Manning is the activity of specifying the number of people needed for each of the jobs in the operation. The task analysis and job design are used to address how many people are needed to perform the required functions and what skill requirements are needed (Meister, 1985). Some principles for manning are shown in the following box.

> The manning should ensure that all the day-to-day activities of the system get done.
>
> The manning should provide for all emergency actions that can reasonably be anticipated.
>
> The manning should schedule normal work and offtime periods, providing enough personnel to keep the system in operation over a long period of time.
>
> The manning should include as few different jobs as possible. The manning should make use of as few different people as possible.
>
> The manning should require as little training time as possible to keep the system up to its full strength. (p. 68, Chapanis, 1977)

Identification of the manning requirements is perhaps the most difficult of the analysis steps. No known analyses have been performed that address the quality of command organization performance as a function of manpower or personnel. As such, few data exist for manning and personnel decisions.

Manning for command and control operations seems to be largely determined by having the proper branch specialties located together at a command post. Dual shift operations are also a factor in determining the number of representatives from a staff specialty. Additional soldiers are included for critical--but often overlooked--"housekeeping" functions (for example drivers, clerks, messengers). Designers need to establish better estimates of the manpower requirements, based on organizational, task, and workload factors.

Workload analysis. Workload is defined as the capacity to perform (Lysaght et al., 1989). It is often considered in relative or sufficiency terms, such as

> How much spare capacity does the soldier have left to apply to emergency situations or additional tasks?
>
> Are capacity demands consistently at high levels, which can lead to overload and, for staff operations, can result in poor decision making?

Workload is a special consideration that is growing in importance as sophisticated equipment is relying on soldiers' cognitive skills as opposed to physical and sensory functions. Of primary concern in command posts is cognitive workload as opposed to physical workload.

The widespread introduction of tactical computer systems in command posts of the future requires careful consideration of manning and workload. Workload analysis is recommended for helping to identify excessive loading conditions and to serve as an impetus for balancing workload levels and manning requirements (or alternatively to modify the functional requirements). Workload analysis should account for peak operations and emergency conditions. Workload needs to be balanced to avoid excessive levels. For workload considerations and allocations both external and internal command post coordination requirements need to be considered.

It is desireable to predict the levels of workload required by tasks and equipment and to take steps to prevent overload conditions. There is no data base of workload in command post operations that could be used to determine empirically the number of soldiers required to perform staff work. Without a baseline

it is difficult to address overload or peak situations. Numerous techniques are available for measuring workload and some of them can be used analytically to predict workload (Lysaght et al., 1989). Analytical techniques which help structure subject matter judgments on workload requirements include the McCracken-Aldrich approach (Aldrich & Szabo, 1986; McCracken & Aldrich, 1984). In this approach workload assessments are made by using numerical ratings with verbal anchors.

> 1 - Automatic, simple association.
> 2 - Sign/signal recognition.
> 3 - Alternative selection.
> 4 - Encoding/decoding, recall.
> 5 - Formulation of plans.
> 6 - Evaluation, judgment.
> 7 - Estimation, calculation, conversion.

Ratings are made for applicable workload components (cognitive, visual, auditory, kinesthetic, and psychomotor) for each task. Tasks are placed along a relative time line. The numerical ratings can be summed or combined in some other fashion (for example, a weighted sum or a multiplicative product) to estimate concurrent workload. If the composite task rating exceeds some pre-established threshold value (for example, a 7 on the visual component), then an overload condition is predicted. Also special questionnaires can be developed (see Babbitt & Nystrom, 1989) to survey subject matter experts on expected levels of workload.

Link analysis. Link analysis is used to produce information on the strength of interrelationships between the different elements in a workspace. All functions must be specified prior to link analysis, and equipment components and personnel need to be identified and clustered into initial groupings.

> The rationale behind the link analysis technique is that the 'best arrrangement' can be found only by optimizing different types of links (such as communication and movement) that are important in the particular system being designed. (p. 422, Thomson, 1972)

Link analysis is recommended at two levels in the sequence of designing SCP. (These correspond to Hendy's category 1 and 2 levels of layout applications, 1984). The first link analysis addresses the groupings of staff elements. The second link analysis is done to 'optimize' the workspace layout within a command post. Closely associated with this is the determination of communication requirements. The applications at division and corps will identify groupings of staff into cells. The applications below division will identify groupings of staff into command posts (tactical, main and rear). The operational

considerations may be trade-offs or constraints that will limit the first link analysis. If a command post has only a single location, the first level link analysis can be skipped. The second link analysis is more detailed and operates on the information flow to arrange soldiers and equipment in a given location.

> The aim of link analysis is to redraw the workplace so as to reduce the number and length of the links and link crossings, which suggest 'activity' and 'confusion' and thereby produce a more efficient design arrangement. The data required for the analysis is:
>
> (a) information on flow requirements,
> (b) flow medium,
> (c) equipment/operator's requirements,
> (d) functional allocation,
> (e) any special constraints. (p.41, Ministry of Defence, 1989)

Many diagrams of command posts identify only the equipment components. In a network diagram for link analysis, equipment and people are identified and referred to as nodes and arcs. The relationships among those nodes are represented as links or arcs.

> The term 'link' refers to any connection between a man and a machine or between one man and another. If, for example, one man must talk to another, this need is represented by a link between them. Similarly, if a man must see the display on a machine or operate a control on a machine, he has a link to the machine. Links include walking, talking, seeing, and movement of material and information. (p. 422, Thomson, 1972)

The identified relationships provide the functional meaning to the network and can be used to represent movement of nodes (people or equipment) and information. Some examples of key relationships are included in the following box.

1. Distance. The distance between nodes.

2. Time. The time required for people, materials, information, and so on to move from one node to another.

3. Frequency. A count of the number of times some relationship occurs between two nodes. Examples would be the number of times an employee walks from one location to another in a work environment and the number of eye movements between two displays on a console.

4. Importance. Usually a rating of the importance between nodes. For example, communications between A and B may be more important than communications between C and D. Importance ratings are often used in planning layouts or arrangements where it is not yet possible to obtain actual distance, time, or frequency measures. (p. 342-343, Laughery & Laughery, 1987)

The physical distance and "ease" of communications among SCP equipment and soldiers will impact the frequency with which the equipment is used. Effectiveness will be reduced if priority communications are delayed because of unnecessary steps in information flow due to unnatural physical movement or excessive communications paths. Link analysis uses the strength and frequency of interchanges through and among the equipment and soldiers to determine good locations and arrangements.

The box on the following page describes the steps for performing a second level link analysis for workspace layout.

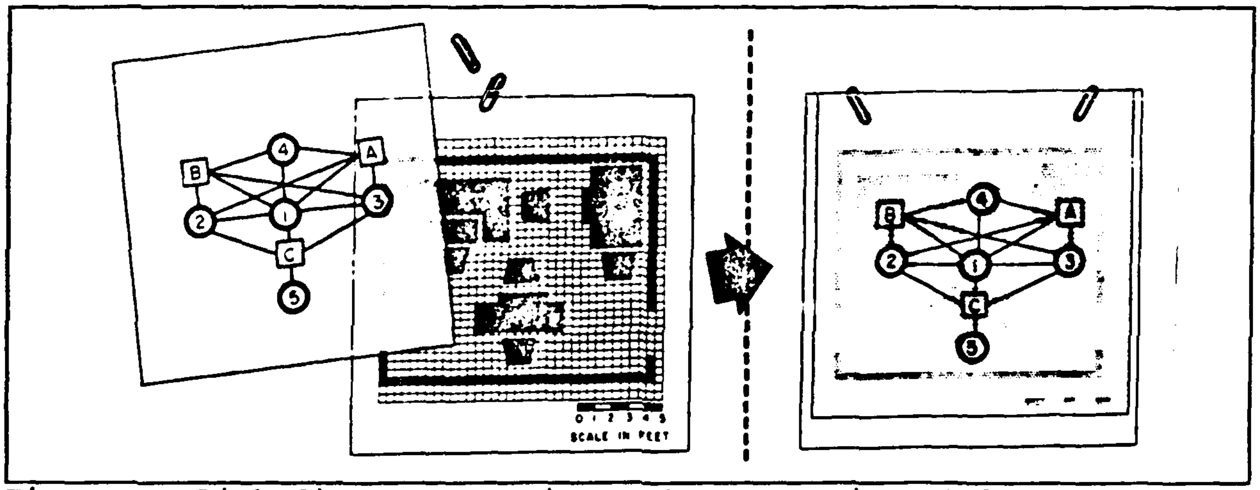


Figure 3. Link diagram superimposed over equipment layout.

Steps to Follow for a Link Analysis

Step 1. Draw a circle for each man in the system and label it with a code number for his particular function (e.g., "1" for radio operator, "2" for navigator, "3" for plotter, etc.)

Step 2. Draw a square for every item of equipment used by a human operator and label it with a code letter (e.g., "A" for radio, "B" for plotting board, "C" for compass, etc.). It makes little difference how the circles and squares are arranged at this point so long as there is some room between them.

Step 3. Draw connecting lines (links) between each man and any other man or men who have direct interaction in the operation of the system.

Step 4. Draw connecting lines between each man and any machines with which he must interact.

Step 5. Redraw the resulting diagram, reducing to a minimum the number of crossing links in order to obtain the simplest possible arrangement.

Where the preceding steps yield many crossings that reveal conflicting requirements for the proximity of men and machines, it is necessary to evaluate the frequency of use, and the importance of each type of link. When this is true, proceed as follows.

Step 6. Evaluate each link by . . . the following. Where both frequency of use and importance of a link must be considered, experienced observers judge the relative weights to be given so as to assign a single composite value [of criticality or strength] to each link.

Step 7. Redraw the diagram so that the links having the higher values are shorter than those having lower link values and reduce the number of crossing links. This is the optimum link diagram.

Step 8. Redraw the link diagram, as necessary, to fit it into the available space or, preferably, design the space to suit the shape of the diagram.

Step 9. Confirm the final link analysis on a scale drawing of the actual positions of the men, machines, and spaces comprising the system. (p 422-3, Thomson, 1972) [see Figure 3]

Application of analysis techniques. There is a tendency to jump too soon to working with the physical elements of design. Almost everyone prefers to deal with what is concrete and tangible, rather than what is abstract and uncertain--as are human behavior and command and control tasks.

The SCP designer must not proceed to the layout of equipment before the appropriate analyses on operational considerations, soldier functions, and manpower are started.

Design Assessment

Design assessment techniques, which are described below, draw heavily from the design techniques that are recommended in this handbook.

Drawings. Sketches and plan view drawings are two basic tools to use in assessing the design and functionality of the workspace. One technique to use in assessment of the drawings is to picture how personnel would operate by recalling some actual or imagined command post exercise. Try to visualize how the workspace layout supports or inhibits performance. Focus on the "choke points" that will check the design the fastest: chaotic periods, final preparation for the commander's briefing, change of shifts, sudden enemy breakthrough, communications jamming, operation in MOPP 4, set-up or tear-down, transferring control to an alternate command post, etc. Think through the entire segment of the scenario before making changes to the design. The important thing to do is to identify potential problems and to resolve them collectively--not piecemeal.

Fault analysis. Fault analysis is a technique using nearly the same visualization process described above. It is related to task analysis; however the focus is on what happens in the human-machine system when emergencies or major failures occur, such as the loss of a critical radio or computer. Performing fault analysis during design assessment will determine how faults might be prevented by prior design action. To get started the designer will need to obtain or make failure predictions. A simple method of conducting a fault analysis is to record the following for each failure considered:

Failure condition.
Effect of the failure.
Possible conditions that would lead to the failure.
How a failure is recognized by a soldier.
Indications which others would have of a failure.
Corrective actions to be taken.
Design changes that could be made.

Stating a failure in terms of how the human would sense the condition (for example, sees no response on the screen when typing on the computer keyboard) is probably the best way to track through the analysis. A simple technique to use is for each failure to complete a worksheet that has seven columns, corresponding to each of the above considerations. It is advised that the technique be used with other methods such as workload analysis and time-based task analysis (James & Grober, 1962).

Link analysis. As described above, link analysis is useful for assessment in addition to design. Link analysis can identify where excessive cross-over interactions occur or where there is inadequate interpersonal or human-machine communication. The link diagram itself is a useful visual aid. Alternative designs can be laid side-by-side for a comparison of the one with the most direct links and the fewest cross overs.

Operations research and numerical methods are available to computationally evaluate the network linkages. An experimental computer program for workspace evaluation, called LOCATE, has been developed.

> [LOCATE] transforms link properties (i.e., length and orientation) into measures of an elemental pair's capability to source and receive information. Link strength functions are chosen to represent human and machine properties which can be characterized by distance and angular dependent relationships: the preferred region for locating visual displays with respect to the normal direction of view, reach envelopes, the angular subtense of a display as a function of viewing distance, or the sound pressure of an audio source. (Hendy, Berger, & Wong, 1989)

Various factors of the LOCATE assessment include the quality of a link, importance of information sent, importance of information received, attenuation of a link by obstructions, distance and angle dependencies, cost, link priority, and relative importance of communication media (i.e., vision, audition, tactile, or movement). Input elements include items of equipment, locations, and personnel.

Simulations. Other computer-based methods are available for evaluating selected aspects of workspace designs. General purpose simulation modeling languages, such as Microsaint[1], can be used to model the soldier tasks that must be performed in a

[1] Microanalysis and Design, Inc., 9132 Thunderhead Drive, Boulder, CO 80302.

given workspace. Microsaint is a menu driven simulation software package. Another software based method, which complements Microsaint, is the Human Operator Simulator (HOS IV) (Harris et al., 1989). HOS IV contains algorithms to simulate various human cognitive, perceptual, and psychomotor actions. For any given workspace design, HOS IV can be used to generate the times it takes to perform various tasks, such as making simple decisions, storing and retrieving information from short term memory, speaking a given number of words, walking a given distance, and others. Both of these software tools operate on personal computers and can be used to evaluate workspace layouts. As with any method or tool there is an initial investment in time and training that is needed for appropriate and effective use. Microsaint can be used after about a week of training and practice.

Mock-ups. Static mock-ups are another tool to use in assessing layouts (see Figure 4). Scaled models provide a test of the goodness of fit of the equipment, while full-scale mock-ups provide the designer a three-dimensional "feel" for the workspace. Once a mock-up is available it is useful to use it as a test vehicle as design issues arise (for example to test a question like: is there access to the electrical distribution box around this computer?). Operational prototypes provide the capability to do partial checks of selected components or to

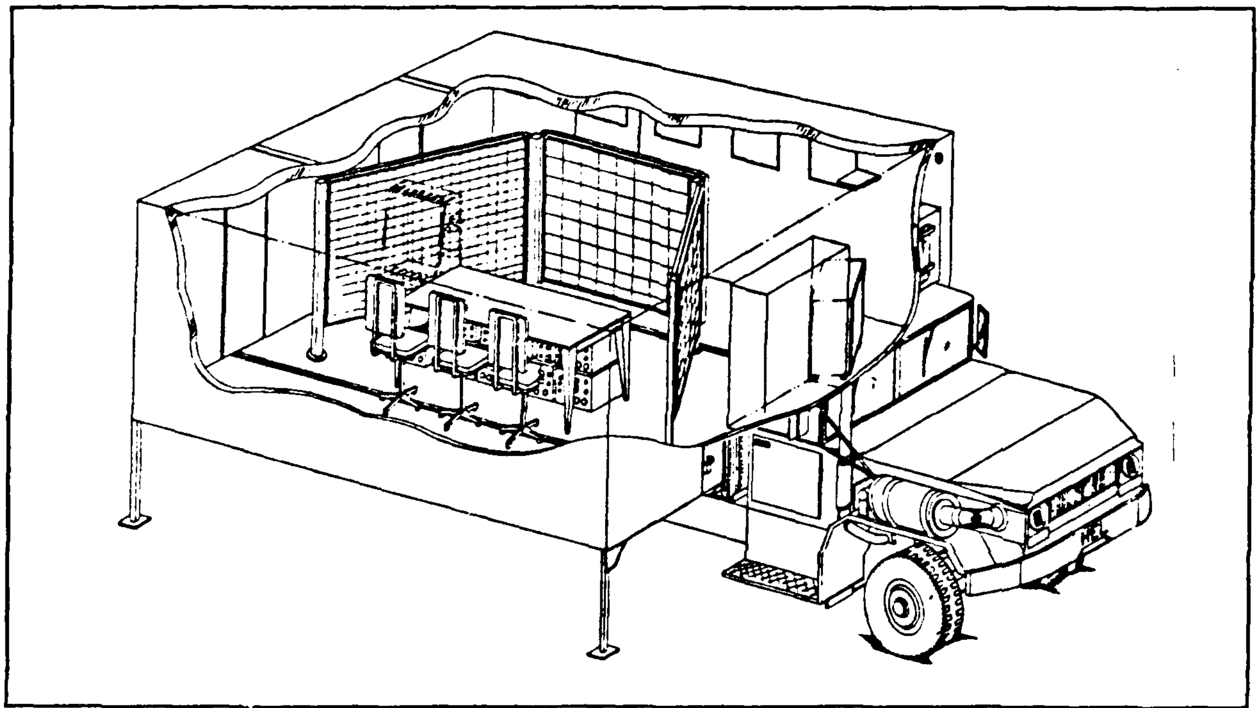


Figure 4. Cut-away drawing of a command post mock-up.

accommodate a fully operating staff. Prototypes that are used in staff exercises can be evaluated using various task analysis and human performance measurement techniques.

As the SCP designer moves from drawing board to operational prototypes, the resource investment increases and the flexibility for changes decrease. The use of all these design tools is recommended to devise a reasonably sound design. The designer should carefully chose the methods and combinations of methods to maximize the design information and remain within the resource allocation.

Design Management

It is recommended that a design management document be generated and used for each command post during the SCP effort. A large amount of information and a large number of actions will be generated during this effort. The designer should make a conscious effort to manage the SCP issues and their resolution. Such a document could be divided into sections, similar to how this design handbook is organized: operational considerations, functions and tasks, job clusters, manpower requirements, workload estimates, link analysis, assessment results, design issues, design conflicts and trade-offs, and resolution of issues. The formality of the management process is not as important as having a technique to record and track design actions and rationale.

3. DESIGN GUIDELINES

The guidelines in this section are not exhaustive of the factors to consider in workspace and soldier equipment interfaces. The ones included have been selected based on their application to command post integration rather than materiel development. Any guidelines are seldom translated directly from a handbook to a design. The application of the guidelines presented here benefit from the prior consideration of operational constraints and the focused information resulting from analyses (covered in Section 2). Overall the arrangement of workspace components must foster a satisfactory environment in which the soldiers operate.

General 'Rules of Thumb'

Consistency in design is an important principle.

Soldiers may be performing duties at several command posts or may operate different workstations within a command post. Supporting expectations in a new or stressful environment will help maintain performance levels. For example, if the brigade command net handset is the one on the right at a workstation and the one on the left is the operations intelligence net, then consideration should be given to using that arrangement for all applicable workstations that a soldier may encounter. Design layouts should be consistent where appropriate.

A common theme in workspace design is to strive for economy of motion.

This applies equally to individual and group tasks. This is the underlying premise of link analysis. Economy of motion relates to physical movement of personnel between locations, to the transfer of information, to operation of equipment by a single operator, and even to eye movement.

For an individual workstation or shared workspace, the recommended order of priority is to design by performing the following steps,

1. Plan the whole, then the detail.
2. Plan the ideal, then the practical.
3. Plan the process and equipment around the system requirements.
4. Plan the layout around the process and equipment.
5. Plan the final enclosure around the layout.
6. Use mockups to evaluate alternate layouts and to check final layout. (p. 382, Van Cott & Kinkade).

The workspace is a dynamic environment. The designer should try to visualize the use of the workspace over time for critical functions, not as a static arrangement of equipment. When dealing with conceptual diagrams of workspace arrangement it is easy to overlook the fact that people are not stationary and that functions may not be fixed in one place.

The SCP designer will have to make tradeoffs among competing factors in workspace layout. The following criteria are listed in order of recommended consideration.

1. Primary visual tasks.
2. Primary controls associated with primary visual tasks.
3. Control and display relationships.
4. Sequence of operation (left to right, top to bottom).
5. Convenience based on frequency of use.
6. Consistency of layouts. (Van Cott & Kinkade, 1972)

Group Workspace

Another primary workspace consideration is designing a facility to provide enough space to accommodate the equipment and personnel and to perform the required tasks. Some basic space considerations include maintaining:

A clearance of 30 to 50 inches in front of equipment and maps.

A work surface area minimum of 30x16 inches.

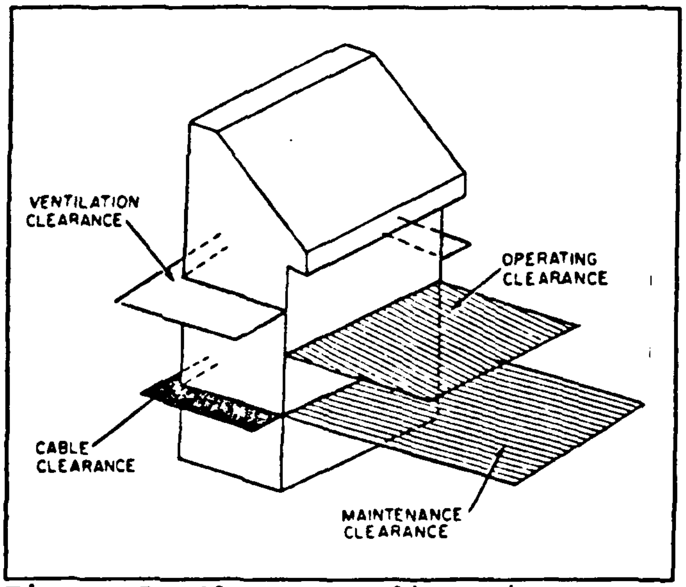


Figure 5. Clearance dimensions around an item of equipment.

A common mistake in initial design stages is failing to take the entire equipment footprint into account. Communications and computer equipment require clearances for ventilation, operation, maintenance, installation, removal, cables, and compartment access. These "softer" clearances need to be established and factored into design by visualizing space usage. (Clearances can be shown in drawings as shaded areas extending from the basic dimensions of equipment.)

Any item should be viewed, operated, manipulated, removed or replaced by a suitably clothed and equipped user with applicable 5th to 95th percentile body dimensions. Applicable values based on anthropometry have been given for various workspace sizing factors. (Anthropometry is the technology of measuring various human physical traits, such as body size, mobility, and strength.) It may be useful to know that anthropometry values exist for most body dimensions and can be used for determining special limits for clearances, limiting dimensions, and adjustable dimensions. Anthropometric tables are available in MIL-STD-1472, MIL-HDBK-759, and DOD-HDBK-743.

The following numbered paragraphs are direct excerpts from MIL-STD-1472.

5.7.4 <u>Common working positions.</u> Anthropometric data for the design and sizing of workspaces involving standing, sitting, stooping, kneeling and supine positions are presented in Table XIX and illustrated in Figure 29. Suitable allowances should be made for heavy clothing or protective equipment when required. In no case shall clearance dimensions be less than the 95th percentile values for men or limiting dimensions be more than the 5th percentile values for women. [Figure 29 and Table XIX are included as Appendix B in this document.]

5.7.1.3 <u>Work space</u>. Whenever feasible, free floor space of at least 4 feet shall be provided in front of each console. For equipment racks that require maintenance, free floor space shall be provided in accordance with the following criteria.

5.7.1.3.1 <u>Depth of work area</u>. Clearance from the front of the rack to the nearest facing surface or obstacle shall not be less than 1.070 m (42 inches). The minimum space between rows of cabinets shall be 200 mm (8 inches) greater than the depth of the deepest drawer (equipment).

5.7.1.3.2 <u>Lateral work space</u>. The minimum lateral work space for racks having drawers or removable equipment shall be as follows (measured from the drawers or equipment in the extended position):

a. For racks having drawers or removable items weighing less than 20 kg (44 pounds): 460 mm (18 inches) on one side and 100 mm (4 inches) on the other.

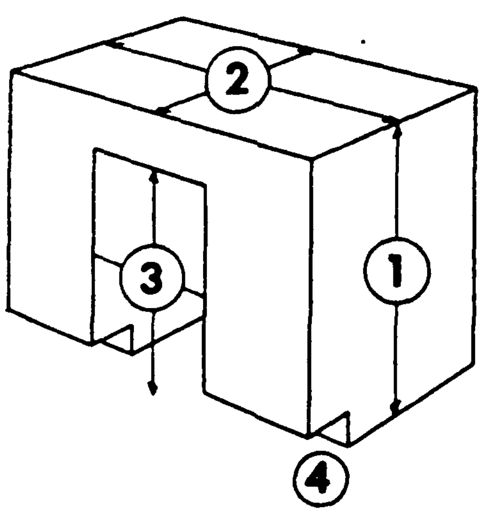
b. For racks having drawers or removable items weighing over 20 kg (44 pounds): 460 mm (18 inches) on each side.

5.7.2 Standing operations

5.7.2.1 Work surface. Work surfaces to support job instruction manuals, worksheets, etc., shall be 915 ±15 mm (36±0.6 inches) above the floor.

5.7.2.2 Display placement, normal. Visual displays mounted on vertical panels and used in normal equipment operation shall be placed between 1.040 m (41 inches) and 1.780 m (70 inches) above the standing surface.

5.7.2.3 Display placement, special. Displays requiring precise and frequent reading shall be placed between 1.270 m (50 inches) and 1.650 m (65 inches) above the standing surface.



Important dimensions to remember in the design of any desk or table are:

1. Working height.
2. Working width and depth.
3. Knee room height and depth.
4. Kick room.

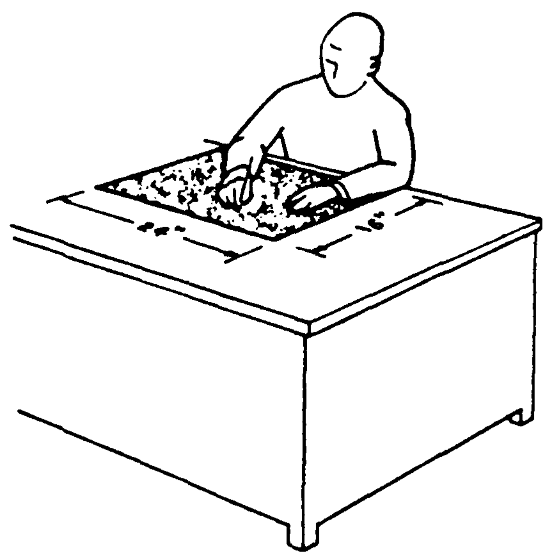


Figure 6. Work surface and desk dimensions.

5.7.3 Seated operations [See Figure 6.]

5.7.3.1 Work surface width and depth. A lateral workspace of at least 760 mm (30 inches) wide and 400 mm (16 inches) deep shall be provided whenever practicable.

5.7.3.2 Work surface height. Desk tops and writing tables shall be 740 to 790 mm (29 to 31 inches) above the floor.

5.7.3.3 Writing surfaces. Where a writing surface is required on equipment consoles, it shall be at least 400 mm (16 inches) deep and should be 610 mm (24 inches) wide, when consistent with operator reach requirements.

5.7.3.4 Seating.

5.7.3.4.1 Compatibility. Work seating shall provide an adequate supporting framework for the body relative to the activities that must be carried out. Chairs to be used with sit-down consoles shall be designed to be operationally compatible with the console configuration.

5.7.3.5 Knee room. Knee and foot room that equals or exceeds the following minimum dimensions shall be provided beneath work surfaces:

a. Height: 640 mm (25 inches)
b. Width: 510 mm (20 inches)
c. Depth: 460 mm (18 inches).

5.7.3.6 Display placement, normal. Visual displays mounted on vertical panels and used in normal equipment operation shall be placed in an area between 150 and 1170 mm (6 and 46 inches) above the sitting surface.

5.7.3.7 Display placement, special. Indicators that must be read precisely and frequently shall be placed in area between 360 and 890 mm (14 and 35 inches) above the sitting surface, and no further from 530 mm (21 inches) laterally from the centerline.

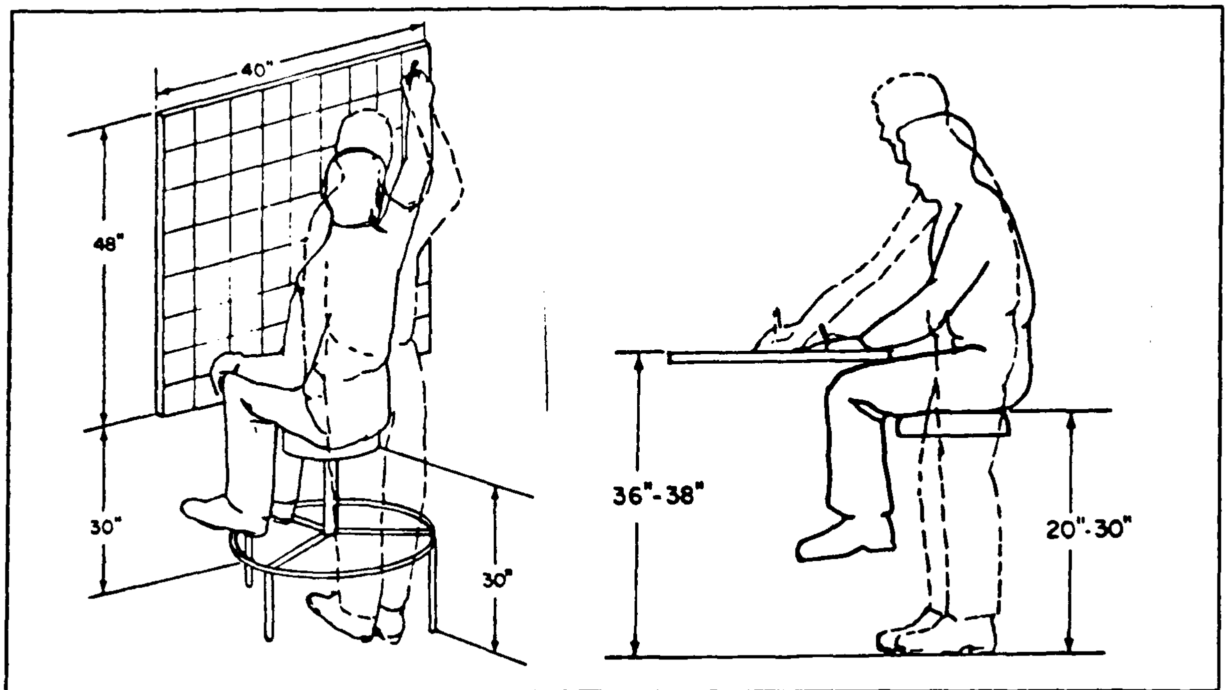


Figure 7. Accommodations for dual sit-stand operations.

Where ceiling height permits, consider using drafting-table or counter work heights (36 inches vs. the typical desk height of 30 inches) and display heights to allow both seated (drafting chair) and standing operations (see Figure 7). Dual sit-stand capabilities will allow mobility, when needed and will be a deterrent to postural fatigue (Van Cott & Kinkade, 1972).

Minimize distractions in the group workspace, that may be caused by attention getting signals from nearby blinking indicator lights or audible signals on radio or computer equipment. For those not directly operating the equipment, shield unnecessary auditory or visual signals. This can be done by reducing the intensity of the signals, attenuating the travel of the signal, and strategic placement and orientation of equipment.

Communications

Interpersonal communication is a primary issue in multiple work places. Common work areas promote the flow of information among people. Proximity of location fosters communications among staff elements. However, with simultaneous tasks being performed, common work areas can create unwanted interferences and distractions. What is an important message to one person or

group may be noise to others. Link analysis (as described in detail in Section 2) will help determine locations based on priority of function and the required proximity to produce the desired frequency and quality of communications among pairs or groups of staff.

Many of the operations within a command post require mobility. Communications equipment should not restrict the mobility; it should accommodate it. Consideration should be given to increasing the accessibility of communication input and speaker devices.

Mobility

Tasks which require the highest mobility (for example, plotting and message passing) need to be allocated sufficient space, based on the priority of function, and should be centrally located to interacting elements. Personnel who are performing the most important function should stay in place and supporting personnel should make any required movement.

Standing permits greater mobility than seated operations, and permits more front-to-rear operating room and greater design latitude. However, seated operation leads to superior performance over prolonged periods. The disadvantages of seated operations are the reduced reach envelope and additional space that is required for access to seating.

Functions and Links

To ease or speed the flow or interaction of personnel performing their required jobs, functions can be handled using three general rules. These rules apply whether a function in question is performed by a single person or by a group of personnel.

Similarity. Similar functions should be located together.

Criticality. Important or critical functions should take design priority over lessor functions.

Frequency. Functions which occur most frequently should be given design priority over less frequent functions.

Unfortunately the principles of similarity, criticality, and frequency can conflict. For example, posting and updating maps is a frequent function in a command post. Though it is a necessary function, it is only a source of data, and so many

other functions can be construed as more critical. These rules need to be weighted to make defendable trade-offs.

Supervision

An obvious consideration of grouping of personnel is the requirement for supervision. Supervisory requirements suggest that supervisors and their people need to be located fairly close depending on the frequency and time required for supervision. Severe environments increase the requirements for supervision. For example in Mission Oriented Protective Posture (MOPP) 4 clothing requirements for supervision increases to ensure proper fluid intake.

Transient Personnel

Command posts require accommodations for transient personnel. Transient personnel are those that are not assigned to a command post or are not always there. They can include the commander, the executive officer, message carriers, subordinate commanders, etc. Special considerations should be given to determine what transient personnel will be sharing the workspace. Access and visual clearance need to be provided, and space needs to be provided whenever information must be shared with another at a workstation (for example, planning tasks using the MCS display). If possible the design should consider the worst case situation (most crowded). An example of this might be the operations briefing in front of the situation map.

Passageways

Command posts must also maintain adequate access and traffic areas. Passageways and aisles are typically open space left in or among tents or shelters to accommodate traffic. Intersections should converge at 90 degrees. Aisles should be kept clear. Aisles should not be located against blank walls because this under-utilizes wall space. Blind corners should be avoided. Paths should be located for minimum distance based on the priority and frequency of function. Aisles should be 54 inches wide for two persons passing (with 44 inches wide the minimum) (see Figure 8). They can be as small as 36 inches wide for one person passing and one standing perpendicular (with 30 inches the minimum) (Thomson, 1972). These dimensions are for typical duty uniform and should be increased for locations where wet and cold weather clothing, MOPP gear, and packs will be worn.

Displays

The following guidelines have been selected to apply to the

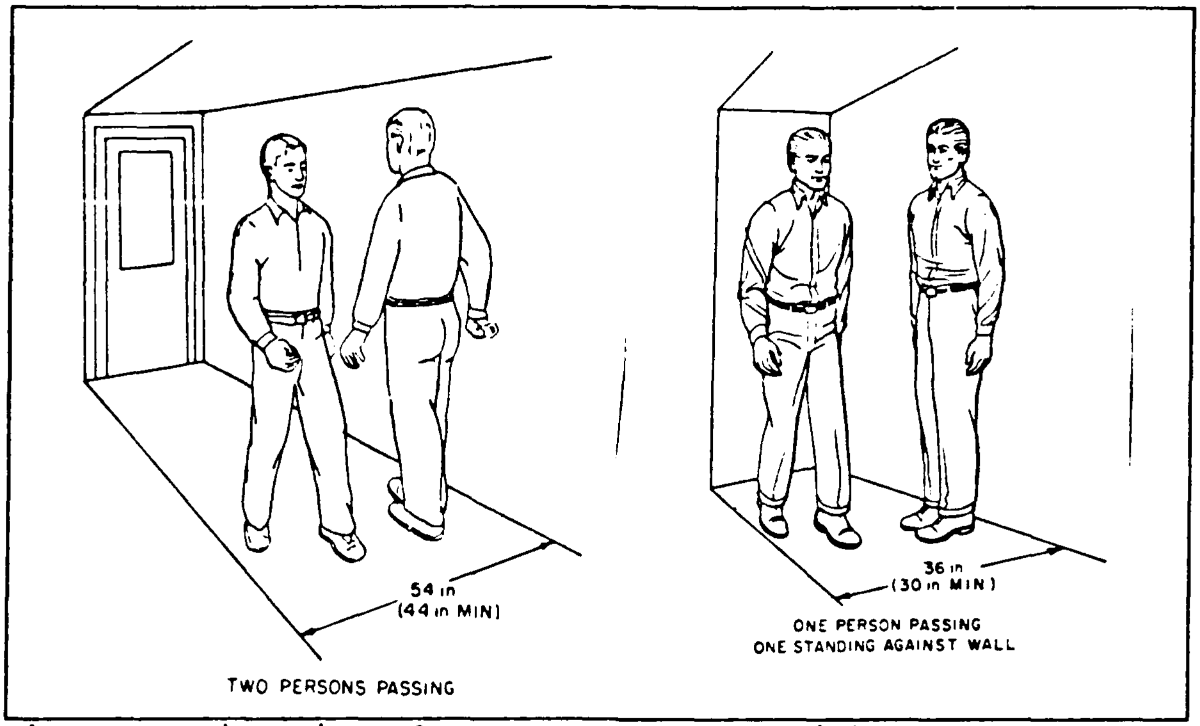


Figure 8. Dimensions for passageways and aisles.

Displays

The following guidelines have been selected to apply to the integration of components, such as a grouping of computers and other equipment and special unit-designed charts. There will not be much latitude for the SCP designer to alter the computer equipment (but several techniques can be applied to reduce fatigue as described in a corresponding section that follows).

Alphanumeric characters, geometric and pictorial symbols should not subtend less than 16 minutes of visual angle (see Figure 9). This translates to a minimum symbol height of .09 inches (2.3 mm) for viewing distances less than 19.7 inches (500 mm) and 1.5 inches (38 mm) for viewing distances from 157.4 to 315.5 inches (4.0 to 8.0 m). To estimate the appropriate symbol height multiply the viewing distance by .0045, or to estimate maximum viewing distance divide a given symbol height by .0045.

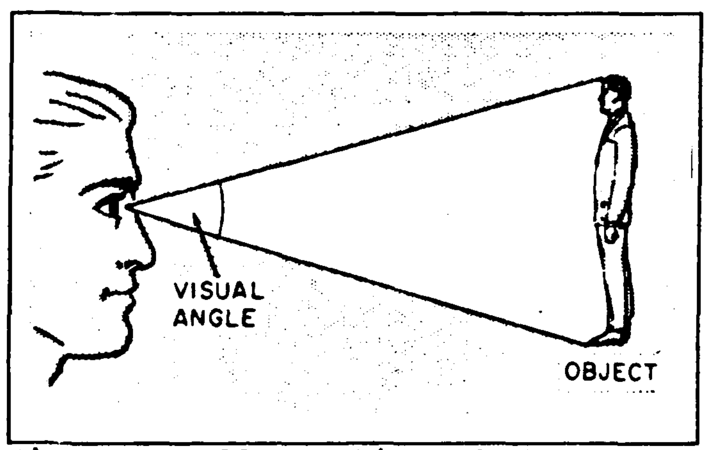


Figure 9. Illustration of the meaning of visual angle.

(These formulas were derived from 5.5.5.15, MIL-STD-1472. Note: the symbol height for the font type of this paragraph is about .11 inches, which indicates an eye to page viewing distance of no more than 24 inches.)

It is also important that consistency is maintained across workstations for placement and types of controls and displays. The following paragraphs from 5.2.1.4.1 through .10 are excerpts from MIL-STD-1472 on the placement of displays.

> 5.2.1.4.1 Location. Displays [including maps and charts] should be located and designed so that they may be read to the degree of accuracy required by personnel in the normal operating or servicing positions without requiring the operator to assume an uncomfortable, awkward or unsafe position.
>
> 5.2.1.4.4 Reflection. Displays shall be constructed, arranged, and mounted to prevent reduction of information transfer due to the reflection of the ambient illumination from the display cover (e.g., acetate overlay).
>
> 5.1.2.4.6 Grouping. All displays necessary to support an operator activity or sequence of activities, shall be grouped together.
>
> 5.1.2.4.7 Function and sequence. Displays shall be arranged in relation to one another according to their sequence of use or the functional relations of the components they represent. They shall be arranged in sequence within functional groups, whenever possible, to provide a viewing flow from left to right or top to bottom.
>
> 5.1.2.4.8 Frequency of use. Displays used most frequently should be grouped together and placed in the optimum visual zone. [The normal line of sight for humans is 15 degrees below horizon. Displays should be in a radius of 10 to 15 degrees around this line of sight.]
>
> 5.1.2.4.9 Importance. Important or critical displays shall be located in a privileged position in the optimum projected visual zone or otherwise highlighted.
>
> 5.2.1.4.10 Consistency. The arrangement of displays within a system shall be consistent in principle from application to application, within the limits specified herein.

The orientation of displays also must be taken into account. Every display has optimal viewing angles and distance that they should be placed from an observer. Displays should be oriented to encompass the intended group of viewers.

Operators should be stationed so that their lines of sight to the display form an angle between 60 and 90 degrees. In no case should this angle exceed 45 degrees. (p. 27, Benel & Benel, 1984)

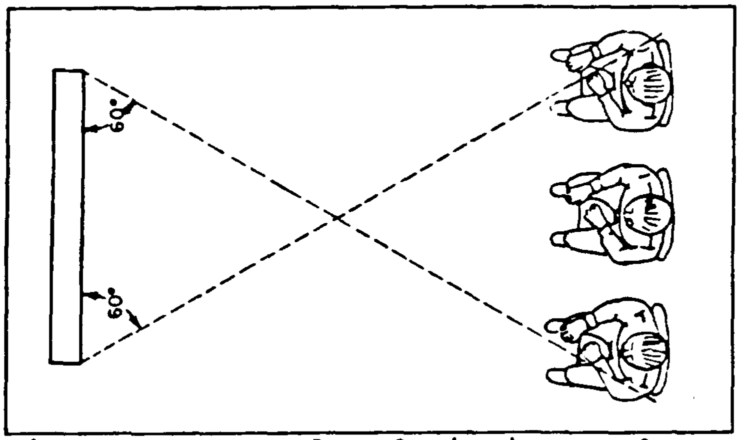


Figure 10. Example of viewing angle.

Also Shurtleff & Wuersch (1979) have developed a technique for identifying the appropriate viewing envelope based on symbol size and brightness contrast ratio. As symbol size and brightness contrast ratio decrease, accuracy readability or target detection drops off sharply. Appropriate viewing areas and distances can be identified for three categories of criticality (based on speed and accuracy levels) in command and control centers. (The algorithm and technique are discussed further in Benel & Benel.) The geometry of display layout is an important design element.

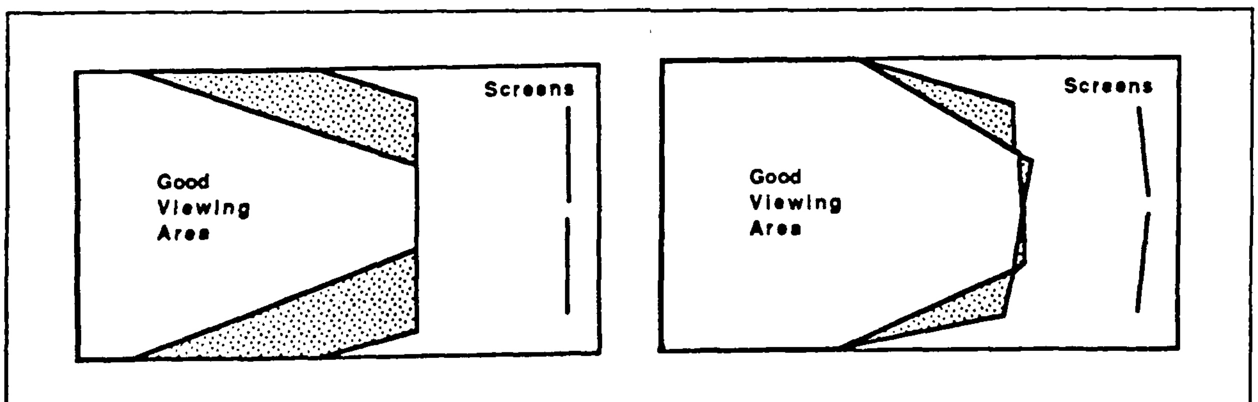


Figure 11. Good viewing area increases with oblique screen positioning.

The following excerpts on large screen displays are from MIL-STD-1472.

5.2.5 Large-screen displays.

5.2.5.1 Use. Large-screen displays may be used when:

a. A group of operators frequently refer to the same information and are required to interact as a team, based on the same information.

b. One or more members of a team of operators must move about, yet require frequent referral to information required to make decisions, but which they cannot carry with them, or do not have displayed at their assigned position(s).

c. Space or other constraints preclude the use of individual displays for each team member to call up commonly-used information.

d. It may be desirable to have general information available to persons who should not interrupt on-going group operations by looking over the shoulder(s) of individual operator(s) to see their individual displays.

5.2.5.2 Avoidance. Large-screen displays shall be used only when the spatial and environmental conditions allow satisfactory observational geometry to insure that all critical operators have appropriate visual access in terms of viewing distance, angle and lack of interference from intervening objects, personnel or ambient lighting.

5.2.5.3 Viewing distance. The display shall not be placed further from an observer than will provide appropriate resolution of critical detail presented on the display. The display shall not be closer to any observer than 1/2 the display width or height, whichever is greater.

5.2.5.4 Physical interruption of view. Large-screen displays shall not be located with respect to critical observers so that the view of the display is obscured regularly by persons moving about--by normal traffic patterns.

When simultaneous displays must be viewed, the goal in workspace design is to overlap the viewing angles to reduce eye, head, and gross body movement (employing the principle of economy of motion). If two displays are frequently compared, then they should be near by. Slightly angling screens towards each other increases the good viewing area for both screens (see Figure 11) (Benel & Benel; Fallesen, 1983).

Fatigue at Computer Workstations

There are two interrelated sources of fatigue experienced at computer workstations. One is posture related due to extended periods at a workstation. Another is due to a concentrated visual effort for long periods. Soldiers operating tactical computers in command posts are especially prone to the physically stressing effects because of rather stark workplace furnishings and the long shifts with intense workload. These stresses are likely to turn up as backaches, neck aches, headaches, burning or "tired" eyes, and potentially as spinal disorders.

The most affected skeletal parts of the body are the neck, back, abdomen, arms and legs (Cakir, Hart & Stewart, 1980). Postural fatigue should not be unexpected, because any posture is harmful if it is maintained for too long a period, and especially tiring if it is fairly static as computer operation is. The layout of the individual computer workspace should do the following:

Permit the individual operator to adjust reading distances (for source documents) and viewing angles.

Encourage changes in working posture, throughout an operator's shift, (adjustable chairs would help).

Provide an adequate work area next to the computer for working documents and carefully position them to accommodate viewing and working with the computer screen and source materials.

Ideally furniture for a computer workstation has separately adjustable keyboard height, screen height, and chair to accommodate 5th percentile females to 95th percentile males. The chair should swivel, be tilt adjustable, and an adjustable or flexing back support. When separately adjustable furniture is not available the following dimensions have been computed based on ANSI/HFS 100-1988 (Human Factors Society, 1988) and MIL-STD-1472.

Seat height	50.0 cm (19.7 inches)
Keyboard support height	71.0 cm (28 inches)
Top of display height	117.7 cm (46.3 inches)

The seat height is set at the popliteal (back of knee) height for 95th percentile male ground troop (MIL-STD-1472). Keyboard support height is taken from ANSI/HFS 100-1988. The display height is computed so the top of the display falls below the horizontal line of sight of the 5th percentile female ground

troop with seat height of 50.0 cm. Because the ANSI/HFS standard requires that lumbar back support be provided for computer operation, it is strongly recommended for SCP facilities.

Adequate work area should be provided next to the computer workstation for source documents and other associated computer task needs. Adequacy will be determined by the specific tasks to be performed at the workstation. A document working area needs to be integrated into the workstation to minimize awkward postures when looking back and forth at the display and when transitioning from keyboard to hardcopy use.

To reduce visual fatigue, operators' vision deficiencies should be appropriately corrected for computer use. Eye to computer distances are slightly longer than typical close reading and writing, so the range of correction for astigmatism, near- and far-sightedness needs to be taken into account. It is impractical to lean forward or back to adjust one's sight distance by moving the upper body and head and still maintain an adequate forearm relationship to the keyboard.

Another way to relieve visual and postural fatigue is to plan for rest cycles or to rotate job duties (among computer and non-computer jobs) while on shift. Computer operation in a command post may be very intense over a prolonged period. A static working posture (with less than ideal furniture), high visual demands, and machine pacing of the tasks can combine to create fatigue. Shifts for computer operation should not follow the typical 12 hour staff duty shift. Consideration should be given to trading duty positions with other staff personnel or to plan shorter shifts with occasional breaks. Industrial guidelines set by the National Institute of Occupational Safety and Health (NIOSH) recommend a fifteen-minute break every two hours of work at a video display terminal with moderate workload (Murray, Moss, Parr, & Cox, 1981). For intensive computer work with repetitive input or other high workload, a fifteen minute break every hour is recommended.

Having the right amount of light will reduce glare and improve the visibility of computer displays. Refer to the box for guidelines on how to reduce glare.

> The light source should not be located within 60 degrees of the viewer's central field-of-view. The light should be diffused and distributed evenly over the work area, with the ratio between light and dark portions of the work surface not exceeding 7:1. Glare can be minimized by keeping the ambient illumination below 300 lux [28 footcandles] with the color of artificial light not exceeding 3000 degrees K. The CRT should be positioned at right angles to the light source, not facing a window, with the artificial light source shielded or reflected from the walls. All surfaces adjacent to the CRT should have a dull matte finish. (p. 23, Benel & Benel, 1984).

Storage

Allocation of space for storage can usually be left for later in design after priority functional requirements have been met. Storage cannot be overlooked, however. Space must be provided for storage of necessary materials used within a command post, such as map sheets, message logs, doctrinal publications, printer paper, replacement parts, and safe. Space also needs to be provided for personnel gear, like combat and protective clothing and weapons, that are temporarily stored while in a shelter. This type of storage needs to be provided for transient personnel as well as assigned personnel. Operation and maintenance of technical equipment require special storage as indicated in MIL-STD-1472.

> 5.7.1.3.4 <u>Storage space</u>. Adequate and suitable space shall be provided on consoles or immediate work space for the storage of manuals, worksheets, and other materials that are required for use by the operational or maintenance personnel. (MIL-STD-1472)

Maintenance

The design of a command post should foster ease of maintenance and repair of equipment items. Several guidelines especially relevant to component integration are listed below:

Eliminate, reduce, or simplify maintenance requirements to reduce workspace design constraints (Rigney, 1977).

Provide space for internal and external accessibility including rear, side, top and bottom access as required by the individual item (MIL-STD-1472).

Provide space for temporary placement of required disassembly during installation, removal, or internal access (e.g., cover removal to access adjustment controls, component replacements) (MIL-STD-1472).

The guidelines on the facing page are taken from MIL-STD-1472 for designing for the maintainer.

Set-up and Tear-down

Considerations for proper cabling and keyed connectors are also important for rapid connection and removal of equipment. In addition to the suggested enhancements identified above, soldier tasks for shelter set-up and tear-down should be specified in detail. A specific sequence of steps should be established for safe and rapid set-up and tear-down. Time lines can be fairly easily set for these operations as well as specific duties assigned to personnel. Simultaneous operations or operations that must be coordinated among several soldiers or locations should receive the closest attention.

Equipment Accessibility

The following are additional guidelines from MIL-STD-1472 on mounting equipment within racks or other units to promote accessibility.

5.9.2.1 Stacking avoidance. Parts should be mounted in an orderly array on a "two-dimensional" surface, rather than stacked one on another (i.e., a lower layer should not support an upper layer, so subassemblies do not have to be removed to access other subassemblies within the equipment).

5.9.2.2 Similar items. Similar items shall utilize a common mounting design and orientation within the unit. This mounting design shall preclude interchange of items which are not functionally interchangeable. Similar items which are not functionally interchangeable shall be made distinguishable by labeling, color coding, marking, etc., to prevent unwanted substitution.

5.9.2.3 Delicate items. Components susceptible to maintenance induced damage through rough handling, static electricity, abrasion, lack of cleanliness or other such factors shall be clearly identified and guarded from abuse both physically and by procedural requirements.

5.9.1.1 Standardization. Standard parts shall be used whenever practicable and should meet the human engineering criteria herein.

5.9.1.2 Special tools. Special tools shall be used only when common hand tools cannot be utilized or when they provide significant advantage over common hand tools. Special tools required for operational adjustment maintenance should be securely mounted with the equipment in a readily accessible location.

5.9.1.3 Modular replacement. Equipment should be replaceable as modular packages and shall be configured for removal and replacement by one person where permitted by structural, functional, and weight limitations.

5.9.1.6 Assembly and disassembly. Equipment shall be capable of being assembled and disassembled in its operational environment by a minimum number of trained personnel wearing clothing appropriate to the operating environment specified for the system maintenance concept.

5.9.1.7 Clothing constraints. Equipment shall be capable of being removed, replaced, and repaired by personnel wearing personal and special purpose clothing and equipment appropriate to the maintenance concept, including NBC protective clothing in an NBC contaminated environment.

5.9.1.8 Errorproof design. Provisions to preclude improper mounting and installation shall include:

a. Physical measures to preclude interchange of items of a same or similar form that are not in fact functionally interchangeable.

b. Physical measures to preclude improper mounting of units or components.

c. Measures (e.g., coding) to facilitate identification and interchange of interchangeable items.

d. Measures (e.g., alignment pins) to facilitate proper mounting of items.

e. Measures to insure that identification, orientation, and alignment provisions include cables and connectors.

The following excerpts from MIL-STD-1472 provide additional guidelines on designing for accessibility. Additional guidelines are presented in MIL-STD-1472 on equipment cases, covers, physical openings, hazards, visual access, fasteners, lifting, mounting, conductors, connectors, and other maintenance-related issues.

5.9.4 Accessibility.

5.9.4.1 Structural members. Structural members or permanently installed equipment shall not visually or physically obstruct adjustment, servicing, removal or replaceable equipment or other required maintenance tasks. Panels, cases, and covers removed to access equipment shall have the same access requirements as replaceable equipment. Mounting provisions shall be directly visually, and physically accessible by the maintainers. Unless required by security considerations, no special tools shall be required for removal or replacement.

5.9.4.2 Large items. Large items which are difficult to remove shall be so mounted that they will not prevent convenient access to other items.

5.9.4.3 Use of tools and test equipment. Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

5.9.4.5 Relative accessibility. Mission critical items which require rapid maintenance shall be most accessible. When relative criticality is not a factor, items requiring most frequent access shall be most accessible.

Environment

Illumination. Illumination is a common area of complaint in command posts. Close work over prolonged periods can quickly lead to visual fatigue and reduced vigilance. Improved illumination can help lessen these effects.

The following light levels (in Footcandles, Ft-C) are recommended (para 5.8.2, MIL-STD-1472):

	Recommended (Ft-C)	Minimum (Ft-C)
General work areas	70	30
Traffic areas	20	10
Emergency lighting		3

There should be a capability for dimming work area lights and to adjust the position of lighting to provide sufficient task area illumination and to reduce glare on map overlays and computer screens. When several displays are used, for example several maps, charts and computer, the lighting shall be balanced across displays such that any two displays do not differ by more than 33 percent (para 5.2.1.2.2, MIL-STD-1472).

Lighting security. Another lighting consideration is designing for light discipline or lighting security. Blackout curtains are a standard for restricting light emissions from command post shelters and should be provided. Most tents provide for double or triple entry flaps to keep light from shining outside. Provisions also need to be taken to shield doorways on shelters and vans. A vestibule can be provided where a soldier has enough room to step into a darkened vestibule, closing the vestibule opening, then entering the lighted shelter. Lighting can be made more secure by following the CECOM Secure Lighting regulation (CECOM-R 70-59, 1988). Some of these guidelines include the following:

Wavelength restriction. Eliminate energy not used by the human eye or otherwise not required by the human operator.

Intensity reduction. The luminance of the light sources must be dimmable down to .5 foot-lamberts or less and also be capable of being turned up to full brightness for daytime use.

Viewing angle restriction. Reduce the viewing angle as much as possible (e.g., light control film and/or rubber hoods).

Indicator lights. Only blue-green, green, and yellow indicator lights may be used on equipments.

Temperature. The ambient temperature for mobile personnel enclosures, such as command post shelters, should be maintained above 10 degrees C dry bulb temperature (50 degrees F) (para 3.3.2, MIL-HDBK-759). Heating systems should not discharge air directly on personnel. Air conditioning should be provided if the "effective temperature" exceeds 29.5 degrees C (85 degrees F) for detail work during prolonged periods (para 3.2.6, MIL-HDBK-759). "Effective temperature" is a combination of dry-bulb temperature, humidity, air movement, and clothing. Acceptable ranges of "effective temperature" vary according to the level of activity. To comply with "effective temperature" limits, dry bulb temperature limits may be increased for tasks requiring minimal physical exertion. (Refer to MIL-HDBK-759 for more information on determining appropriate temperatures.)

Ventilation. Ventilation requirements include fresh air and the movement of air. Paragraph 5.8.1.2 in MIL-STD-1472 provides requirements for the following:

Rates of introducing ventilation air.
Rates of air velocity.
Prevention of introducing contaminated air.

Potential contaminants and hazards in command posts come from the exhaust of engines and heaters. Contaminants include aldehydes, carbon monoxide, nitrous oxide, and sulfur dioxide. Fouled air can cause eye, respiratory, and nausea problems. It is important to keep the combustion exhausts separated from ventilation intakes.

Auditory environment. The auditory environment in command posts should be controlled by keeping noise below permitted levels to permit effective communications.

> 4.1.1 Total System Noise - Subsystems, sets, groups and units, including such items as air conditioners, heaters, I/O devices (e.g., printers, typewriters), and auxiliary equipment, shall be selected and integrated in such a manner that the noise produced by the entire system does not exceed the requirements of this standard. (MIL-STD-1474)

For frequent telephone or radio use or frequent direct communication up to 5 feet, noise should not exceed 65 dB(A) (5.1.1.1, MIL-STD-1477). Since typical conversational speech at five feet is about 60 dB (Deatherage, 1972), adequate speaker volume and an attentive listener would be required in an environment close to this noise limit. For required communications up to 15 feet, noise should not exceed 55 dB(A)

(5.8.3.3.3, MIL-STD-1472). Noise can be attenuated by staggered placement of reflective surfaces, staggered placement of doors, and corridors, and using sound absorbing surfaces (5.8.3.4.2, MIL-STD-1472).

5.3.8.2.1 Monitoring of speakers. When several channels are to be monitored simultaneously by means of loudspeakers, the speakers shall be mounted at least 175 mrad (10 degrees) apart in the horizontal plane frontal quadrant, ranging radially from 45 degrees left to 45 degrees right of the operator's normal forward facing position. (MIL-STD-1472)

The placement of audio and visual alarms and signals needs to be given consideration in group workplaces so the right personnel will detect and be able to discriminate among various signals. The signals must have the proper intensity, duration, and other distinguishing characteristics to pinpoint the warning that is intended to be conveyed.

To discourage auditory detection by enemy forces, MIL-STD-1474 establishes noise limits (see Table 3 in MIL-STD-1474). When noise is in the neighborhood of 65 dB at 25 meters, the source can be detected as far away as 2000 meters (depending on weather and site characteristics).

Biomechanical stress. Another important design goal is to reduce biomechanical stress whenever possible. Avoid workspace designs that require frequent overhead reach or holding one's hands above the shoulders for prolonged periods (for example, map boards that are too high). Also avoid prolonged stressing postures such as forward flexing of the neck and forward reach of the shoulder and arm. (These considerations apply to the design or selection of seating and work surface heights and angles. Also refer to the section on computer workstation design.)

Weight limits that have been set for lifting and carrying are generally lower than commonly thought. For female soldiers the range is from 37 to 44 pounds and for males it is from 56 to 87 pounds (5.9.11.3.1., MIL-STD-1472). This is based on a standard cube of 18"x18"x12" with uniform weight distribution. Larger cubes or more frequent carries cause a lowering in the maximum lifting limits.

Consider providing a cushioned surface, such as carpet or rubber mats, for prolonged standing positions. These materials provide noise dampening and insulating benefits, as well.

Van enclosures. Paragraph 5.12.7.2 in MIL-STD-1472 sets design requirements for vans used as shelters for personnel.

These features should be maintained in the design for the SCP application. The ceiling height should not be less than 1.890 m (74.5 inches), including the standing work space over or under cables, lights, or other objects. Steps, stairs, or ladders should be provided when van floors are more than 460 mm (18 inches) above ground level. Access doors should have provisions for securing doors in both open and closed positions. Also inclinometers should be provided to aid in leveling the van ± 2 degrees in front to rear and side to side aspects.

Safety

Safety is a major concern in design and is the driving factor for many of the design guidelines that have been presented in previous Sections (for example, discrimination among audible signals, minimal illumination levels, adequate maintenance access). Appendix C taken from paragraph 6.1.1, MIL-HDBK 759 provides an excellent discussion of the principles of safety as they relate to human behavior. Some of these principles apply only to the design of specific pieces of equipment, but most pertain to the design and operation of SCP. Other safety guidelines for SCP include the following (adapted from Leeson, 1989; Thomson, 1972).

Doors should be easily accessible and sufficient clearance provided into the aisle when it is swung open.

Alternate exits should be provided in command post shelters and vehicles.

Adequate traffic area illumination should be provided, as well as emergency lighting.

Engine and generator exhausts should be routed away from van and tent enclosures.

Provisions should be made to secure heavy equipment, such as radios and computers, to prevent shifting or falling on personnel during operation and set-up and tear-down.

Cabling should be secured out of the way to prevent breaking, snagging, or tripping.

Inter-vehicular ramps and other connections, such as those among expansible vans (which are elevated about 44 inches above the ground) should provide fairly level surfaces from one shelter to another. Ropes, chains or guardrails can be used to thwart falls from stairs or open platform ends.

Common ground should be established among electrical equipment and vehicles.

Safety and warning labels need to be appropriately displayed and legible.

There needs to be safe access to overhead storage on both the inside and outside of shelters and vehicles with adequate steps and handholds.

Fuel lines should be appropriately shielded or ruggedized within personnel compartments.

Finally, the designer must be careful that several infrequent, low-consequence, or marginal hazards do not combine to add up to major safety problems.

4. GUIDELINE IMPLEMENTATION

To integrate and summarize the recommended design approach some implementation guidance is provided in this Section.

Integrating the Design

In the analytical phase of the design process, the designer should address the following questions:

What are the operational goals and constraints of the command post and the force it supports?

What is the single most important thing that this command post does that supports the commander?
What are the supporting functions that serve to accomplish this mission?
What are the tasks that have to be performed to do this function?
How are these tasks done, by whom, how often?
What is the flow of information and the interaction among staff?

Who will be available to perform in the command post and are they sufficient to meet the manning and workload requirements?
Do they have the proper base of experience and knowledge?
What are the common job elements of the functions and tasks?
Of these commonalities, what appear as the clusters of activities?

At this point, the designer has performed the initial analyses up to workspace layout. The designer has specified the operational goals and constraints, has performed a functional analysis, and identified a functional flow and flow of information. Available reference materials such as mission training plans and doctrinal tactics, techniques, and procedures have been used. Tasks have been identified along with their associated importance by criticality and frequency. The first level link analysis should have been completed to identify personnel and functional grouping requirements for sub-elements of the command post. An initial list of equipment has been identified based on baseline TOE needed to perform those functions and the numbers and skills of soldiers have been estimated and workload has been balanced among the specialties and soldiers.

The bulk of the designer's time has been spent on decomposing the mission, functions, and tasks and putting all of that into a logical framework. After this it is time to work with the physical elements of the design -- the workspace layout. Here it is appropriate to start with the second level of

link analysis to determine personnel and equipment locations within the common work area. In the iterations and trade-offs in constructing alternate conceptual layouts the following questions should be addressed:

What is the focal point of work within the command post?
Is it individual in nature or group in nature?
Will the command post house a collection of individual workplaces?
What is the relative importance of group interaction for the functions?

For given scenarios, what are the most important functions that need to be done to have a favorable effect on commanded or supported units?
What are the associated items of equipment that ought to be near or centrally located for these most important things?

Who is involved in doing these most important things?
Who are they?

How can the strong links be fostered and how can possible confusion and distractions be lessened?

The recommended design approach requires a substantial investment in consideration to the functional requirements and the range of soldiers that perform the functions. By following some of these basic questions in design analyses and applying the design guidelines, a better SCP should emerge -- one that has been designed to fit the soldiers.

Tailoring the Guidelines

The following are examples of 'rules of thumb' that can be generated from the general guidelines presented in this handbook. These can be used as criteria in generating designs and making trade-offs among alternative concepts. These examples are based on observations of potential problems with previous command post layouts.

General. Allow for viewing of computer screens and print-outs by other than the primary operator (for example, commander, chief of staff, executive officer).

Allow sufficient aisle space or access space to get to each workstation without requiring movement of others.

Optimize the configuration geometry of multiple displays that need to be used simultaneously (e.g., unit status charts and situation maps) by orienting adjacent displays at an angle.

Expansible vans. Locate heavy items of equipment in the center of the expansible shelter (alternatively place on locking casters or sliding mechanisms to re-locate easily).

Place maps on curbside and roadside walls in shelter carriers, and allow enough work area for the necessary numbers of people in front of the maps (avoid conflicting work space usage nearby, such as passageways).

Use the three entrances wisely, close off one of them to limit traffic strategically or to use as additional work space against the wall. Ensure there are adequate emergency exits available.

M577 and extension tent. Avoid using the M577 ramp as a work area in an elevated platform mode as it blocks M577 access and creates a potential hazard.

Standardized Integrated Command Post System (SICPS) tent. There is a potential tripping hazard where floor panels overlap (Wettig, 1990). Heavy items, such as table legs and safes can be placed on these junctions to hold them tightly across the enclosure and securely down. A slipping hazard also exists when snow, ice, or water are tracked onto the floor (Smith, 1989).

SICPS light sources need to be augmented for most tasks. Two 40 watt fluorescent lights provide less than 30 footcandles of illumination at typical SICPS work areas (Wettig, 1989).

Computer workstations should be located away from the natural illumination coming through windows and doors and reflected off nearby walls.

SICPS integrated shelter. Placement of equipment should not obstruct use of the secondary access hatch (Leeson, 1989).

Design Assistance

The combat developer need not bear the entire burden of design. He or she should take full advantage of any opportunities for assistance in this work. The designer can look to activities that have performed related technical work in past and ongoing efforts in materiel acquisition programs, such as the Standardized Integrated Command Post System (SICPS), Army Tactical Command and Control System (ATCCS), and Force Level

Control System (FLCS). Technical findings are available for many of these programs, as well as from other command and control research and development efforts. Some of the information can be obtained through literature searches, but the best resource will be the technical and operational experts that are familiar with a particular issue. *Human factors practitioners* located at TRADOC centers, Army laboratories, research and development centers, Army Materiel Commands (AMCs), test boards, analysis activities, and evaluation agencies can be contacted for information, guidance, and assistance.

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APPENDIX A

Excerpts from Army Command and Control System Employment Concept

3.0 ATCCS ENVIRONMENT

ATCCS automation must fit into and endure a multifaceted environment. ATCCS computers and communications must be employable in all theaters, each characterized by a variety of threat, environmental, and operating conditions. The Army units that the system will support will make up the organizational environment. The various operational modes in which these units will be engaged pose another aspect of the environment. Functionally, ATCCS automation must fit in among a constellation of other systems belonging to the Army, other U.S. Armed Services, and other nations. Physically, the environment is made up of the battlefield installation settings in which ATCCS component systems will reside. Additionally, ATCCS computers and communications will have to operate in a hostile tactical battlefield environment. In this environment, the enemy will try to create conditions intended to degrade operations of command and control personnel, computers, and communications. Lastly, since ATCCS automation will handle classified information, security considerations constitute another dimension of the environment.

3.1 Organizational Environment

The Army will field ATCCS computers and communications throughout the entire force (that is, both the Active Component and the Reserve Component), as structured according to the Army of Excellence (Lidy et al., 1985). Thus, the ATCCS will support the command and control of the numbers of and types of units shown in Table 3-1. Note that the units listed include those in the Reserve Component of the force, in addition to the Active Component.

3.2 Operational Mode Summary

The Army will employ the ATCCS under potentially all climatic conditions in peacetime and combat environments. Combat environments will range from low-intensity conflict through mid-intensity conflict to conflicts that include the use of nuclear, biological, and chemical weapons. At any level of conflict, forces will engage the enemy in a number of operational missions. Table 3-2 summarizes from FM 100-5 Operations the expected missions to be encountered by the various Army force types (DA, 1986d). Table 3-3 summarizes the environmental conditions that the same types of forces may encounter.

The command posts of these forces will displace frequently to avoid detection and attack. Displacements using vehicles are estimated to take place over primary roads 10 percent of the time, secondary roads 70 percent of the time, and cross country 20 percent of the time. About 10 percent of all displacements will take place under blackout conditions. Actual

TABLE 3-1
U.S. ARMY FORCE STRUCTURE

	Heavy	Light	Cavalry	Aviation	Total
Corps Total	4	1	0	0	5
Active	4	1	0	0	5
Reserve	0	0	0	0	0
Division Total	14	14	0	0	28
Active	10	8	0	0	18
Reserve	4	6	0	0	10
Divisional Brigade Total	42	42	0	28	112
Active	30	24	0	18	72
Reserve	12	18	0	10	40
Separate Brigade/Armored Cavalry Regiment Total	10	12	7	8	37
Active	3	2	3	0	8
Reserve	7	10	4	8	29
Divisional Battalion Total	140	126	28	0	294
Active	100	72	18	0	190
Reserve	40	54	10	0	104
Separate Brigade Battalion Total	30	36	12	0	78
Active	3	6	9	0	18
Reserve	27	30	3	0	60

Source: Lidy, 1985.

Notes: Active divisions may include 1 roundout brigade or battalion of the Reserve Component; there are 3 maneuver brigades and 1 combat brigade attack aviation/combat aviation brigade per division; and there are 10 maneuver battalions per heavy division, 9 per light division, and 3 per separate brigade.

TABLE 3-2
MISSIONS PERFORMED BY TACTICAL FORCES

Mission	Corps		Division					
	Lt	Hvy	Arm	Mech	Abn	AA	LI	Mtz
Offensive Operations								
Movement To Contact	N	N	N	N	N	N	N	N
Hasty Attack	N	N	N	N	N	N	N	N
Deliberate Attack	N	N	N	N	N	N	N	N
Exploitation	N	N	N	N	N	N	N	N
Pursuit	N	N	N	N	N	N	N	N
Defensive Operations								
Defense	N	N	N	N	N	N	N	N
Counter/Spoiling Attack	N	N	N	N	N	N	N	N
Retrograde	N	N	N	N	N	N	N	N
Delay	N	N	N	N	N	N	N	N
Withdrawal	N	N	N	N	N	N	N	N
Defense and Breakout of Encircled Forces	N	N	N	N	N	N	N	N
Rear Area Protection	N	N	N	N	N	N	N	N
Other Operations								
Reconnaissance in Force	N/A	N/A	L	L	N/A	L	L	L
Demonstration	L	L	L	L	N/A	L	L	L
Raid	N/A	N/A	L	L	N/A	L	L	L
Feint	L	L	L	L	N/A	L	L	L
Relief To Continue Attack	N	N	N	N	N	N	N	N
Relief To Continue Defense	N	N	N	N	N	N	N	N
Stabilization Operations	N	L	L	L	L	M	N	M
Reserve	N	N	N	N	N	N	N	N

Key:

AA	Air Assault	M	Medium Probability of Assignment
Abn	Airborne	Mech	Mechanized
ACR	Armored Cavalry Regiment	Mtz	Motorized
Arm	Armored	N	Normal Mission
L	Low Probability of Assignment	N/A	Not Applicable
LI	Light Infantry	Sep	Separate

Source: DA, 1986d.

TABLE 3-2
MISSIONS PERFORMED BY TACTICAL FORCES (Concluded)

Mission	Brigade/Regiment ACR	Sep Arm	Sep Mech	Sep LI
Offensive Operations				
Movement To Contact	N	N	N	N
Hasty Attack	N	N	N	N
Deliberate Attack	N	N	N	N
Exploitation	N	N	N	N
Pursuit	N	N	N	N
Defensive Operations				
Defense	L	N	N	N
Counter/Spoiling Attack	L	N	N	N
Retrograde				
Delay	N	N	N	N
Withdrawal	N	N	N	N
Defense and Breakout of Encircled Forces	L	N	N	N
Rear Area Protection	M-L	N	N	N
Other Operations				
Reconnaissance in Force	N	L	L	L
Demonstration	N	L	L	L
Raid	N	L	L	L
Feint	N	L	L	L
Relief To Continue Attack	L	N	N	N
Relief To Continue Defense	L	N	N	N
Stabilization Operations	L	L	L	N
Reserve	N	N	N	N

TABLE 3-3
CONDITIONS ENCOUNTERED BY TACTICAL FORCES

Operational Conditions	Corps		Division					
	Lt	Hvy	Arm	Mech	Abn	AA	LI	Mtz
Combat in Urban Terrain	N	L-M	L	L	L	N/A	N	N
Desert Warfare	L	N	N	N	L	L-M	L	M
Jungle Warfare	N	L	L	L	L	L-M	L	M
Mountain Warfare	N	L	L	L	L	L	N	M
Winter Warfare	N	N	N	N	N	N	N	N
River Crossings	N	N	N	N	N	N	N	N
NBC Warfare	N	N	N	N	N	N	L	N
Amphibious Operations	N	L	N/A	N/A	N/A	N/A	N	N/A
Airborne/Airmobile	N	N/A	N/A	N/A	N	N	L	N/A

Operational Conditions	Brigade/Regiment			
	ACR	Sep Arm	Sep Mech	Sep LI
Combat in Urban Terrain	L	L	L	N
Desert Warfare	N	L	L	L
Jungle Warfare	L	L	L	N
Mountain Warfare	N/A	L	L	N
Winter Warfare	N	N	N	N
River Crossings	N	N	N	N
NBC Warfare	N	N	N	N
Amphibious Operations	N/A	N/A	N/A	N
Airborne/Airmobile	N/A	N/A	N/A	N/A

Key:
- AA — Air Assault
- Abn — Airborne
- ACR — Armored Cavalry Regiment
- Arm — Armored
- L — Low Probability of Assignment
- LI — Light Infantry
- M — Medium Probability of Assignment
- Mech — Mechanized
- Mtz — Motorized
- N — Normal Mission
- N/A — Not Applicable
- Sep — Separate

Source: DA, 1986d.

percentages will vary according to theater and mission. Table 3-4 displays representative command post and facility mobility characteristics for various echelons and includes displacement frequencies, distances, and times. These command posts and facilities will displace by section, requiring the remaining section or designated replacement command post to execute the functions of the displacing command post temporarily.

Army forces will use the ATCCS for peacetime in-garrison support, during times of crisis leading up to war, and in full-scale war operations. In each of these modes, patterns of use will vary.

3.2.1 Wartime Use

The Army is designing ATCCS automation first and foremost to support the command and control required to achieve an assigned mission under wartime conditions. In general, ATCCS systems will support all classes of users with the applications support discussed in succeeding sections. When a unit is placed in reserve, ATCCS automation usage will be somewhat different: ATCCS systems will monitor the situation with a view primarily towards supporting contingency planning by the commander and his staff. If time permits, individual training and limited staff training will be conducted to educate replacement personnel.

In a wartime environment, units engaged in combat will use the ATCCS automation on a 24-hour basis under wartime conditions every day of the year. ATCCS automation functions must meet this usage requirement despite scheduled maintenance, displacement, or destruction due to enemy action. Actual system loading, however, will vary according to the tempo of battle. For example, if night combat operations are infrequent, ATCCS loading during the night may consist primarily of combat service support information processing and information processing in support of preparatory efforts for the next day's combat operations. ATCCS will use primarily tactical communications and tactical power supplies to support its operations. Similarly, ATCCS computers and communications generally will be used in both mounted and dismounted modes with frequent displacements. Finally, depending upon the theater and mission, ATCCS will support a full range of joint and combined interfaces.

3.2.2 Peacetime Use

While primarily intended for use during combat, portions of ATCCS automation will be used in support of peacetime garrison operations. The use of ATCCS automation during peacetime will permit its operators to become very familiar with its operations, thereby making wartime use that much easier. Selected Combat Service Support and Intelligence/Electronic Warfare systems will be used to support day-to-day administration, logistics, maintenance, and intelligence analysis operations, respectively.

TABLE 3-4
REPRESENTATIVE MOBILITY CHARACTERISTICS OF
COMMAND POSTS AND FACILITIES

Echelon	Dwell Time (hours)	Breakdown/ Setup Time (minutes)	Distance Moved (kilometers)	Travel Time at 20 km/hr (minutes)	Standby Time per 24 hours (hours)
Corps	6-26	80-90	30-70	90-210	6.5-13
Division	2-24	6/60	20-60	60-180	5-16
Brigade/ Regiment	1-8	3-6/30	10-50	30-150	7-17.5
Battalion/ Squadron	1-4	3-6/30	10-30	30-90	7.5-16
Company/ Troop	1	3-6	10	30	0

Source: CACDA, 1987b.

Since combat units frequently have the responsibility for administering the base that they occupy, special administrative applications may be required to accomplish this. The ATCCS will need to support selected in-garrison combat support operations as well, such as construction engineer and aviation. The force commander and his staff may be assisted by the ATCCS when they are engaged in in-garrison contingency planning. Similarly, when simulation or other training aids are available, all portions of the ATCCS will be used to conduct individual, staff, unit, or multi-unit training while in-garrison or on field exercises.

Under peacetime conditions, ATCCS automation usage and characteristics will differ from wartime in several ways. ATCCS automation generally will be used for less than 24 hours a day during most days of the week, unless field training is conducted. Instead of tactical wide area communications means, ATCCS automation will use primarily the host nation public telephone and telegraph network, base communications, or components of the Defense Communications System to support its communications needs. Similarly, ATCCS hardware generally will be used in a dismount mode since it will be located in garrison buildings. Under these circumstances, commercial sources instead of tactical sources likely will furnish primary power. Interfaces with base ADP systems or those deployed by U.S. Army major commands may be advantageous for some of these in-garrison applications.

3.2.3 Use During Transition

The Army will use portions of ATCCS automation also to support operations during crises or during the transition from peace to war. Selected Combat Service Support, Intelligence/Electronic Warfare, and Maneuver systems will be used to support contingency and deployment planning and execution conducted by the commander and his staff. Special applications software and data bases dedicated to base operations will be removed or transferred to base ADP systems and replaced by contingency plans and wartime data. Stateside units will use the system to support mobilization, if required, and training, if time permits. They also may use the ATCCS automation to support their transit to ports of embarkation through the generation of movement orders and the provision of status reports. When units disembark, commanders and their staffs will use ATCCS component systems to support the combining of unit resources with prepositioned equipment, limited training, and the movement of the unit to its assigned positions with movement orders, intelligence processing, and status reporting.

During transition, most portions of ATCCS generally will be used 24 hours a day during all days of the week, except while in transit. ATCCS will use primarily the public telephone and telegraph network to support its initial communications needs until it transitions to tactical communications. Similarly, ATCCS hardware will be used initially in a

dismount mode that will transition to mobile mode or a storage mode while in transit aboard strategic airlift or sealift. Under these circumstances, primary power initially could be provided by commercial sources before the ATCCS transitions to tactical power sources. Most interfaces will be in transition as units switch from their peacetime interfaces with base ADP systems or those deployed by U.S. Army major commands (such as the Forces Command) to those interfaces with the systems used by both the theater Army component of U.S. unified commands and with allied commands, such as the U.S. Army-Europe Theater Army Command and Control System and the North Atlantic Treaty Organization (NATO) Central Army Group Command and Control Information System.

3.3 External System Environment

The external interfaces of the ATCCS are a reflection of the required interfaces that tactical forces establish at corps and below with outside organizations. Figure 3-1 displays these outside organizations and their relationships to the Army at corps and below. The ATCCS fits in the areas labeled "Tactical Units-Corps and Divisions" and "Subordinate Tactical Units-Brigades, Regiments, Battalions, and Squadrons". From the figure one notes that tactical organizations must interact with installations within the United States and with Army component commands, theater Army functional/area commands, and wartime allied commands outside of the United States.

The ACCS will include the ATCCS, and the ATCCS will interface with other parts of the ACCS. The ACCS is the aggregate of systems through which Army commanders employ and sustain military forces in a theater of operations. The ACCS comprises the ATCCS and the Theater Army Command and Control System (CACDA, 1987[a]). As shown in Figure 3-2, the ATCCS must interface with joint and combined command and control systems within the theater to support the employment of tactical resources, and with Theater Army Command and Control Systems to support the sustainment of these resources.

In situations where U.S. Army Forces operate in a joint or combined environment, the Army requires that ATCCS subsystems also have numerous external interfaces to systems of other U.S. Services (the Navy, Air Force, and Marines), allies (such as NATO nations), and echelons above corps (such as U.S. unified commands). Automated systems within each of the five battlefield functional areas will implement these interfaces, all of which are described in the ABIC 86 (CACDA, 1986). The table in Appendix B shows, by battlefield functional area, which ATCCS subsystems are required to interface with which external systems.

3.4 Installation Settings

ATCCS computers and communications will support users located in numerous command posts and facilities, including tactical operations centers, command posts, fire direction centers, weapon or sensor control facilities, and unit headquarters at all echelons. These facilities will range in size from that of a heavy corps main command post (composed of numerous shelters dispersed over an area from 2 to 20 square kilometers) to a forward observation post (composed of a two-man team carrying all of their gear). The composition of these locations may include any of the following installation settings:

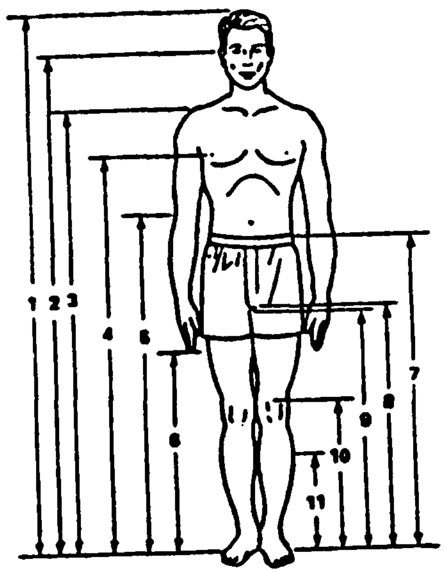
1. Tracked vehicles
2. Wheeled vehicles
3. Light vehicles
4. Tents
5. Expandible vans
6. Aircraft, such as the BLACK HAWK utility helicopter
7. Dismounted
8. Ground mounted
9. Buildings

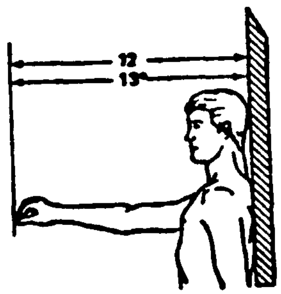
3.5 Threat Environment

Although the U.S. Army most likely will engage enemy forces in low intensity conflict, threat forces of the Warsaw Pact represent the most serious opposition likely to face the U.S. Army (CACDA, 1987[a]). These threat forces place a high priority on the disruption or destruction of their enemy's command, control, communications, and intelligence systems. The Warsaw Pact forces likely will apply a variety of resources against U.S. Army systems, including lethal and nonlethal attack means employed to deceive, deny, degrade, and destroy portions of the ATCCS. The Army expects that this enemy will attack ATCCS shelters and command centers with conventional munitions, electronic warfare, chemical and biological agents, directed energy weapons, nuclear weapons, airborne/airmobile forces, and unconventional or special operations forces.

APPENDIX B

Selected Anthropometric Data for US Army Soldiers





*SAME AS 12; HOWEVER, RIGHT SHOULDER IS EXTENDED AS FAR FORWARD AS POSSIBLE WHILE KEEPING THE BACK OF THE LEFT SHOULDER FIRMLY AGAINST THE BACK WALL.

FIGURE 23. STANDING BODY DIMENSIONS

TABLE XIII. STANDING BODY DIMENSIONS

	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
WEIGHT (kg)	55.5	60.4	46.4	91.6	96.0	74.5
STANDING BODY DIMENSIONS						
1 STATURE	162.8	164.2	152.4	185.6	187.7	174.1
2 EYE HEIGHT (STANDING)	151.1	152.1	140.9	173.3	175.2	162.2
3 SHOULDER (ACROMIALE) HEIGHT	133.6	133.3	123.0	154.2	154.8	143.7
4 CHEST (NIPPLE) HEIGHT *	117.9	120.8	109.3	136.5	138.5	127.8
5 ELBOW (RADIALE) HEIGHT	101.0	104.8	94.9	117.8	120.0	110.7
6 FINGERTIP (DACTYLION) HEIGHT		61.5			73.2	
7 WAIST HEIGHT	96.6	97.6	93.1	115.2	115.1	110.3
8 CROTCH HEIGHT	76.3	74.7	68.1	91.8	92.0	83.9
9 GLUTEAL FURROW HEIGHT	73.3	74.8	66.4	87.7	88.1	71.0
10 KNEECAP HEIGHT	47.5	46.8	43.8	58.6	57.8	52.5
11 CALF HEIGHT	31.1	30.9	29.0	40.6	39.3	36.6
12 FUNCTIONAL REACH	72.6	73.1	64.0	90.9	87.0	80.4
13 FUNCTIONAL REACH, EXTENDED	84.2	82.3	73.5	101.2	97.3	92.7
	PERCENTILE VALUES IN INCHES					
WEIGHT (lb)	122.4	133.1	102.3	201.9	211.6	164.3
STANDING BODY DIMENSIONS						
1 STATURE	64.1	64.6	60.0	73.1	73.9	68.5
2 EYE HEIGHT (STANDING)	59.5	59.9	55.5	68.2	69.0	63.9
3 SHOULDER (ACROMIALE) HEIGHT	52.6	52.5	48.4	60.7	60.9	56.6
4 CHEST (NIPPLE) HEIGHT *	46.4	47.5	43.0	53.7	54.5	50.3
5 ELBOW (RADIALE) HEIGHT	39.8	41.3	37.4	46.4	47.2	43.6
6 FINGERTIP (DACTYLION) HEIGHT		24.2			28.8	
7 WAIST HEIGHT	38.0	38.4	36.6	45.3	45.3	43.4
8 CROTCH HEIGHT	30.0	29.4	26.8	36.1	36.2	33.0
9 GLUTEAL FURROW HEIGHT	28.8	29.4	26.2	34.5	34.7	31.9
10 KNEECAP HEIGHT	18.7	18.4	17.2	23.1	22.8	20.7
11 CALF HEIGHT	12.2	12.2	11.4	16.0	15.6	14.4
12 FUNCTIONAL REACH	28.6	28.8	25.2	35.8	34.3	31.7
13 FUNCTIONAL REACH, EXTENDED	33.2	32.4	28.9	39.8	38.3	36.5

*BUSTPOINT HEIGHT FOR WOMEN

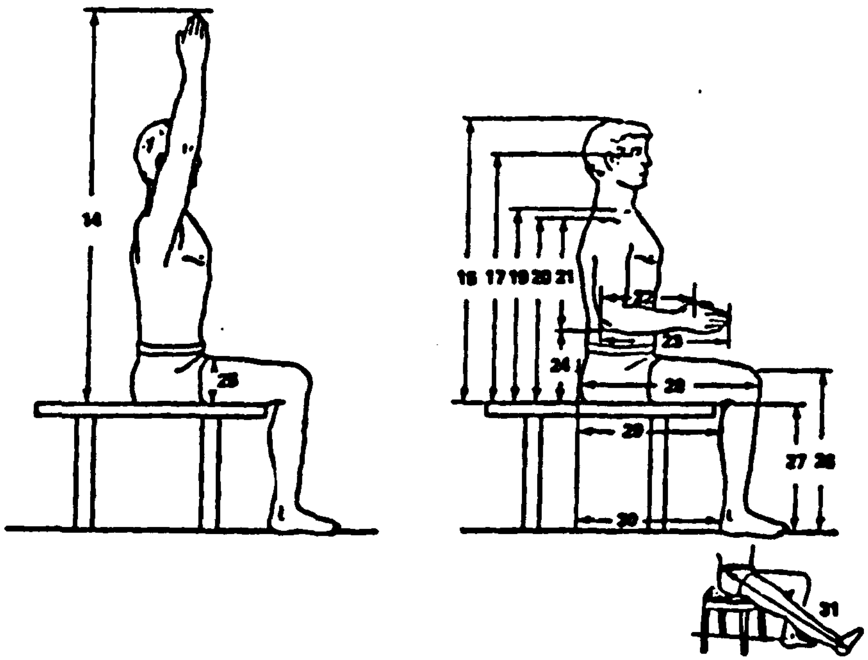


FIGURE 24. SEATED BODY DIMENSIONS

TABLE XIV. SEATED BODY DIMENSIONS

	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
SEATED BODY DIMENSIONS						
14 VERTICAL ARM REACH, SITTING	128.6	134.0	117.4	147.8	153.2	139.4
15 SITTING HEIGHT, ERECT	83.5	86.7	79.0	96.9	98.8	90.9
16 SITTING HEIGHT, RELAXED	81.5	83.6	77.5	94.8	96.5	89.7
17 EYE HEIGHT, SITTING ERECT	72.0	73.6	67.7	84.6	86.1	79.1
18 EYE HEIGHT, SITTING RELAXED	70.0	71.6	66.2	82.8	84.0	77.9
19 MID-SHOULDER HEIGHT	56.6	58.3	53.7	67.7	69.2	62.5
20 SHOULDER HEIGHT, SITTING	54.2	54.6	49.9	65.4	65.9	60.3
21 SHOULDER—ELBOW LENGTH	33.3	33.2	30.8	40.2	39.7	36.6
22 ELBOW—GRIP LENGTH	31.7	32.6	29.6	38.3	37.9	35.4
23 ELBOW—FINGERTIP LENGTH	43.8	44.7	40.0	52.0	51.7	47.5
24 ELBOW REST HEIGHT	17.5	18.7	16.1	28.0	29.5	26.9
25 THIGH CLEARANCE HEIGHT		12.4	10.4		18.8	17.5
26 KNEE HEIGHT, SITTING	49.7	46.9	46.9	60.2	60.9	55.5
27 POPLITEAL HEIGHT	39.7	38.4	38.0	50.0	47.7	45.7
28 BUTTOCK—KNEE LENGTH	54.9	55.9	53.1	65.8	65.5	63.2
29 BUTTOCK—POPLITEAL LENGTH	45.8	44.9	43.4	54.5	54.6	52.6
30 BUTTOCK—HEEL LENGTH		46.7			56.4	
31 FUNCTIONAL LEG LENGTH	110.6	103.9	99.6	127.7	120.4	118.6
	PERCENTILE VALUES IN INCHES					
SEATED BODY DIMENSIONS						
14 VERTICAL ARM REACH, SITTING	50.6	52.8	46.2	58.2	60.3	54.9
15 SITTING HEIGHT, ERECT	32.9	33.7	31.1	38.2	38.8	35.8
16 SITTING HEIGHT, RELAXED	32.1	32.9	30.5	37.3	38.0	35.3
17 EYE HEIGHT, SITTING ERECT	28.3	30.0	26.6	33.3	33.9	31.2
18 EYE HEIGHT, SITTING RELAXED	27.6	28.2	26.1	32.6	33.1	30.7
19 MID-SHOULDER HEIGHT	22.3	23.0	21.2	26.7	27.3	24.6
20 SHOULDER HEIGHT, SITTING	21.3	21.5	19.6	25.7	25.9	23.7
21 SHOULDER—ELBOW LENGTH	13.1	13.1	12.1	15.8	15.6	14.4
22 ELBOW—GRIP LENGTH	12.5	12.8	11.6	15.1	14.9	14.0
23 ELBOW—FINGERTIP LENGTH	17.3	17.6	15.7	20.5	20.4	18.7
24 ELBOW REST HEIGHT	6.9	7.4	6.4	11.0	11.6	10.6
25 THIGH CLEARANCE HEIGHT		4.9	4.1		7.4	6.9
26 KNEE HEIGHT, SITTING	19.6	19.3	18.5	23.7	23.6	21.8
27 POPLITEAL HEIGHT	15.6	15.1	15.0	19.7	18.8	18.0
28 BUTTOCK—KNEE LENGTH	21.6	22.0	20.9	25.9	25.8	24.9
29 BUTTOCK—POPLITEAL LENGTH	17.9	17.7	17.1	21.5	21.5	20.7
30 BUTTOCK—HEEL LENGTH		18.4			22.2	
31 FUNCTIONAL LEG LENGTH	43.5	40.9	39.2	50.3	47.4	46.7

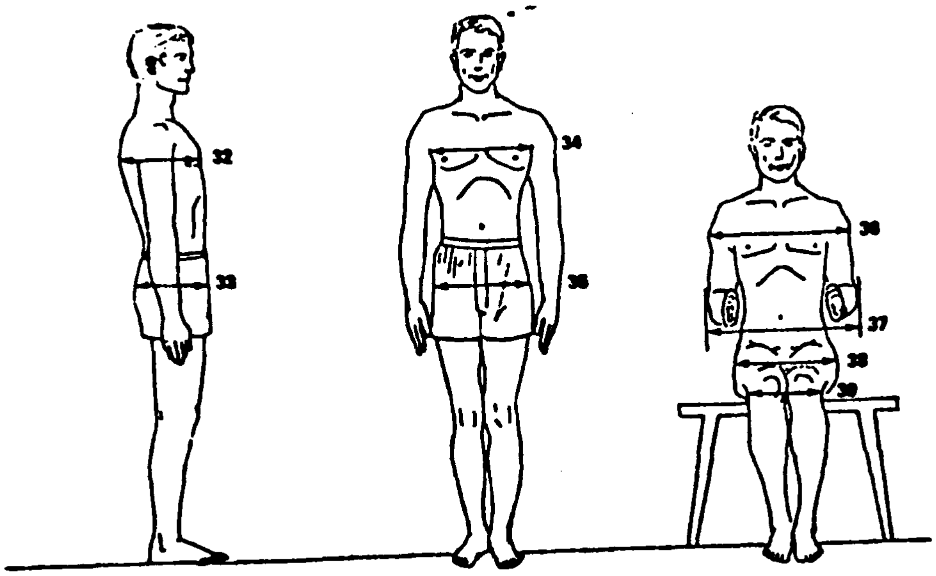


FIGURE 25. DEPTH AND BREADTH DIMENSIONS

TABLE XV. DEPTH AND BREADTH DIMENSIONS

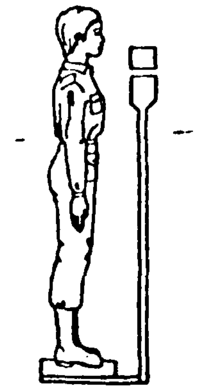
	PERCENTILE VALUES IN CENTIMETERS					
	5th PERCENTILE			95th PERCENTILE		
	GROUND TROOPS	AVIATORS	WOMEN	GROUND TROOPS	AVIATORS	WOMEN
DEPTH AND BREADTH DIMENSIONS						
32 CHEST DEPTH*	18.9	20.4	19.6	26.7	27.8	27.2
33 BUTTOCK DEPTH		20.7	18.4		27.4	24.3
34 CHEST BREADTH	27.3	29.6	25.1	34.4	38.5	31.4
35 HIP BREADTH, STANDING	30.2	31.7	31.5	36.7	38.8	39.5
36 SHOULDER (BIDELTOID) BREADTH	41.5	43.2	38.2	49.8	62.6	45.8
37 FOREARM–FOREARM BREADTH	39.8	43.2	33.0	53.6	60.7	44.9
38 HIP BREADTH, SITTING	30.7	33.3	33.0	38.4	42.4	43.9
39 KNEE–TO–KNEE BREADTH		19.1			25.5	
	PERCENTILE VALUES IN INCHES					
DEPTH AND BREADTH DIMENSIONS						
32 CHEST DEPTH*	7.5	8.0	7.7	10.5	11.0	10.7
33 BUTTOCK DEPTH		8.2	7.2		10.8	9.6
34 CHEST BREADTH	10.8	11.6	9.9	13.5	15.1	12.4
35 HIP BREADTH, STANDING	11.9	12.5	12.4	14.5	15.3	15.6
36 SHOULDER (BIDELTOID) BREADTH	16.3	17.0	15.0	19.6	20.7	18.0
37 FOREARM–FOREARM BREADTH	15.7	17.0	13.0	21.1	23.9	17.7
38 HIP BREADTH, SITTING	12.1	13.1	13.0	15.1	16.7	17.3
39 KNEE–TO–KNEE BREADTH		7.5			10.0	

*BUST DEPTH FOR WOMEN

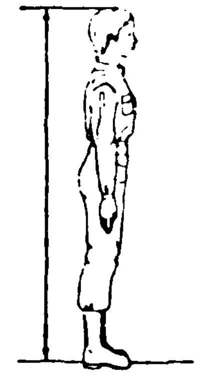
TABLE XIX. ANTHROPOMETRIC DATA FOR COMMON WORKING POSITIONS

	PERCENTILE VALUES IN CENTIMETERS			
	5th PERCENTILE		95th PERCENTILE	
	MEN	WOMEN	MEN	WOMEN
1. WEIGHT – CLOTHED (KILOGRAMS)	58.6	48.8	90.2	74.6
2. STATURE – CLOTHED	168.5	156.8	189.0	178.7
3. FUNCTIONAL REACH	72.6	64.0	86.4	79.0
4. FUNCTIONAL REACH, EXTENDED	84.2	73.5	101.2	92.7
5. OVERHEAD REACH HEIGHT	200.4	185.3	230.5	215.1
6. OVERHEAD REACH BREADTH	35.2	31.5	41.9	37.9
7. BENT TORSO HEIGHT	125.6	112.7	149.8	138.6
8. BENT TORSO BREADTH	40.9	36.8	48.3	43.5
9. OVERHEAD REACH, SITTING	127.9	117.4	146.9	139.4
10. FUNCTIONAL LEG LENGTH	110.6	99.6	127.7	118.6
11. KNEELING HEIGHT	121.9	114.5	136.9	130.3
12. KNEELING LEG LENGTH	63.9	59.2	75.5	70.5
13. BENT KNEE HEIGHT, SUPINE	44.7	41.3	53.5	49.6
14. HORIZONTAL LENGTH, KNEES BENT	150.8	140.3	173.0	163.8
	PERCENTILE VALUES IN INCHES			
1. WEIGHT – CLOTHED (POUNDS)	129.1	107.6	198.8	164.5
2. STATURE – CLOTHED	66.4	61.8	74.4	70.3
3. FUNCTIONAL REACH	28.6	25.2	34.0	31.1
4. FUNCTIONAL REACH, EXTENDED	33.2	28.9	39.8	36.5
5. OVERHEAD REACH HEIGHT	78.9	73.0	90.8	84.7
6. OVERHEAD REACH BREADTH	13.9	12.4	16.5	14.9
7. BENT TORSO HEIGHT	49.4	44.4	59.0	54.6
8. BENT TORSO BREADTH	16.1	14.5	19.0	17.1
9. OVERHEAD REACH, SITTING	50.3	46.2	57.9	54.9
10. FUNCTIONAL LEG LENGTH	43.5	39.2	50.3	46.7
11. KNEELING HEIGHT	48.0	45.1	53.9	51.3
12. KNEELING LEG LENGTH	26.2	23.3	29.7	27.8
13. BENT KNEE HEIGHT, SUPINE	17.6	16.3	21.1	19.5
14. HORIZONTAL LENGTH, KNEES BENT	59.4	55.2	68.1	64.5

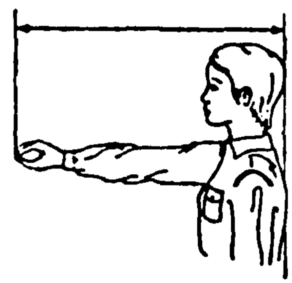
*See Figure 28 for illustration of each measurement.



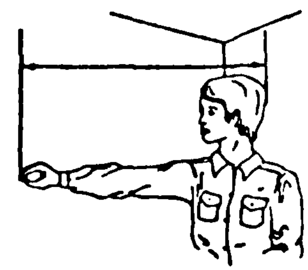
(1) WEIGHT (CLOTHED) WEARING FATIGUES & COMBAT BOOTS; STANDING IN CENTER OF SCALE



(2) STATURE (CLOTHED) STANDING ERECT; HEELS TOGETHER; WEIGHT DISTRIBUTED EQUALLY ON BOTH FEET. MEASURED FROM STANDI SURFACE TO TOP OF HEAD

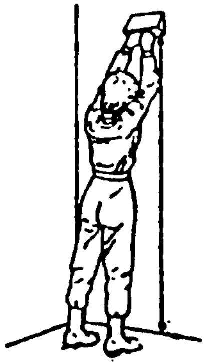


(3) FUNCTIONAL REACH – STANDING ERECT; LOOKING STRAIGHT AHEAD; BOTH SHOULDERS AGAINST WALL; RIGHT ARM HORIZONTAL. MEASURED FROM WALL TO TIP OF INDEX FINGER

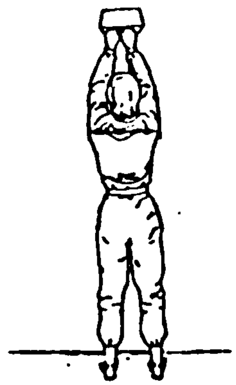


(4) FUNCTIONAL REACH, EXTENDED–STANDING ERECT; LOOKING STRAI AHEAD; RIGHT SHOULDER EXTENC AS FAR FORWARD AS POSSIBLE WH BACK OF LEFT SHOULDER FIRMLY AGAINST WALL; ARM HORIZONTAL MEASURED FROM WALL TO TIP OF INDEX FINGER.

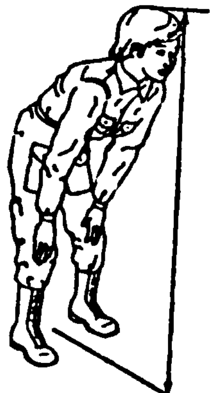
FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES



(5) OVERHEAD REACH HEIGHT – STANDING WITH HEELS 23 cm APART AND TOES 15 cm FROM WALL; ARMS EXTENDED OVERHEAD WITH FISTS TOUCHING AND AGAINST WALL; 1st PHALANGES HORIZONTAL. MEASURED FROM FLOOR TO HIGHEST POINT ON 1st PHALANGES



(6) OVERHEAD REACH BREADTH – STANDING WITH HEELS 23 cm APART AND TOES 15 cm FROM WALL; ARMS EXTENDED OVERHEAD WITH FISTS TOUCHING AND AGAINST WALL; 1st PHALANGES HORIZONTAL. MEASURED HORIZONTALLY ACROSS ARMS OR SHOULDERS, WHICHEVER IS WIDER.

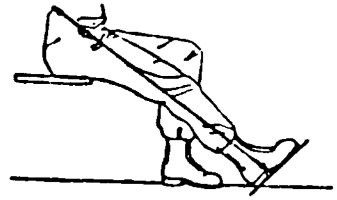


(7) BENT TORSO HEIGHT – STANDING WITH FEET 30 cm APART; BENDING OVER AND PLACING PALMS OF THE HANDS ON KNEECAPS; ELBOWS AND KNEES LOCKED; LOOKING FORWARD; HEAD TILTED AS FAR BACK AS POSSIBLE. MEASURED FROM FLOOR TO TOP OF HEAD.

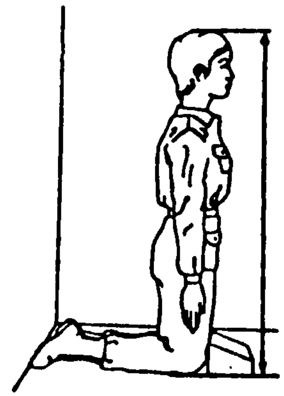
(8) BENT TORSO BREADTH – STANDING WITH FEET 30 cm APART; BENDING OVER AND PLACING THE PALMS OF THE HANDS ON KNEECAPS; ELBOWS AND KNEES LOCKED; LOOKING FORWARD; HEAD TILTED AS FAR BACK AS POSSIBLE. MEASURED AS MAXIMUM HORIZONTAL DISTANCE ACROSS SHOULDERS.

FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES (CONTINUED)

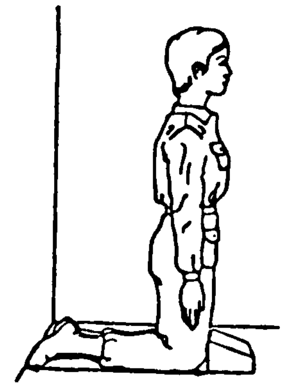
(9) OVERHEAD REACH, SITTING – SITTING ERECT; RIGHT SIDE AGAINST WALL; RIGHT ARM EXTENDED UPWARD WITH PALM FLAT AGAINST WALL AND FINGERS EXTENDED. MEASURED FROM SITTING SURFACE TO TIP OF MIDDLE FINGER.



(10) FUNCTIONAL LEG LENGTH – SITTING ERECT ON EDGE OF CHAIR; RIGHT LEG EXTENDED FORWARD WITH KNEE STRAIGHTENED. MEASURED FROM HEEL ALONG AXIS OF LEG TO POSTERIOR WAIST.



(11) KNEELING HEIGHT – KNEELING WITH TOES EXTENDED AND LIGHTLY TOUCHING REAR WALL; TORSO ERECT WITH ARMS HANGING LOOSELY AT SIDES. MEASURED FROM FLOOR TO TOP OF HEAD.



(12) KNEELING LEG LENGTH – KNEELING WITH TOES EXTENDED AND LIGHTLY TOUCHING REAR WALL; TORSO ERECT WITH ARMS HANGING LOOSELY AT SIDES. MEASURED FROM WALL TO ANTERIOR PORTION OF BOTH KNEES.

FIGURE 29. ANTHROPOMETRIC DATA FOR WORKSPACES (CONTINUED)

APPENDIX C

Safety Excerpts from MIL-HDBK-759

SECTION 6

SAFETY

6.1 General. Safety is always an important consideration. In evaluating equipment's safety characteristics, some of the areas which must be reviewed are:

(a) Failure modes and hazardous effects.

(b) Electrical and electronic safety factors.

(c) Mechanical safety factors, including hydraulics and pneumatics.

(d) Toxicity.

(e) Radiation.

6.1.1 Principles of Human Behavior Related to Safety. There are principles about human behavior that can help designers design safe equipment. The principles below are based on how people actually use equipment in the field, and on what actually does happen to that equipment. These principles give at least a partial answer to why people make errors, misuse equipment, and do other unsafe things. Armed with such knowledge of why people err, the designer can avoid many rather subtle temptations that give users opportunities to take chances.

Principle 1: If the equipment provided is insufficient or inadequate, users will modify it, or improvise, so they can get the job done. Improvised equipment leads to improvised procedures and, often, to hazards.

Principle 2: Procedures should be definite and comprehensive. Some users need little encouragement to discard procedures and do what they please, which is often the wrong thing to do.

Principle 3: People often feel that "it can't happen here." They assume that, if someone gets hurt (or damages equipment) by disregarding instrustions, it will be someone else in some other place. Because people feel safer than they are, procedures must be as nearly foolproof as possible. And since procedures, in turn, are shaped by the equipment itself, the equipment design must be structured so it encourages safe use allowing a minimum of opportunity for operators to use it unsafely.

Principle 4: Once a safety problem has arisen, taking corrective action does not necessarily eliminate it. The correction may not be sufficient, or may not be appropriate, or may even fail to attack the problem's cause. If so, the problem may reappear elsewhere or in some other way. Corrective actions should always be followed up to verify that they have really solved the problem.

Principle 5: Not all safety problems can be anticipated from studying concepts and blueprints. Thorough safety analysis requires realistic tests with mockups and prototypes. No matter how simple and foolproof a concept looks on paper, try it before finalizing the design.

Principle 6: If the equipment is designed so it does not operate as the user's expectancies and stereotypes lead him to think it will, he will eventually make mistakes.

Principle 7: If unsafe possibilities are designed into the equipment, no warning note in a technical manual can eliminate them completely. Warning notes do have a limited, supplementary value in making mishaps less probable. However, many users may not have read them, or may not remember them, or may not even know where to find them. Warning notes do not prevent safety problems.

Principle 8: Accidents are so unreal to some people that they do not appreciate how careless performance can cause accidents. Before these individuals take their assignment seriously, and do it thoroughly and carefully, they must actually see equipment damaged or people injured.

Principle 9: Equipment should be designed so it is inherently safe to use, rather than relying on special safety training to prevent accidents. Not all users get such training, even when it is "required." Some users will have had outdated training, or related training, or catch-as-catch-can training.

Principle 10: Equipment users tend to be unimaginative; they do not visualize the consequences of unsafe acts. These people only realize a practice is dangerous after they have seen someone get hurt.

Principle 11: Certain individuals seemingly prefer to work under hazardous conditions, as if their bravery makes the job more important.

Principle 12: Negativistic people may be more likely to do something because they have been told not to do it. Tell such people "don't," and regardless of personal risk, they do it. Instructions, like warning notes, are not enough to insure operators will work safely.

Principle 13: Some operators will try to use equipment in incorrect and unintended ways. Designers should consider the possibilities for errors--listing the possible mistakes the operator can make, and their consequences--and try to design equipment so incorrect use will do as little harm as possible.

Principle 14: Some accidents occur because technicians cannot (or do not) identify parts correctly. Whenever the user may injure himself or damage a part because he does not know what it is, designers should provide complete, legible, understandable identification.

Principle 15: All designs require compromises, but every effort should be made to minimize conditions which predispose to accidents. If undesirable conditions are tolerated without making a real effort to improve them, they often seem to multiply and interact to produce serious safety problems.

Principle 16: Equipment should be designed so it can be used safely without undue nuisance. If the procedures for safe operation seem needlessly difficult or burdensome, people tend to avoid doing what seems unnecessary. Ideally, equipment should be designed so it is easier to use it safely then to use it unsafely.

Principle 17: Designers must anticipate that operators do make mistakes, and assure that these inevitable mistakes are not likely to injure personnel or damage the equipment. For example, users must be given at least some on-the-job training with operational equipment; these partially trained personnel must be expected to make errors.

Principle 18: The designer must understand all of the requirements his equipment has to satisfy; only by comprehending these requirements can he assure that the equipment will meet them.

Principle 19: The operator's care in using and maintaining items tends to be related to their complexity and cost. People are most careful of complicated, expensive items. Conversely, operators tend to neglect simple, inexpensive items because they seem relatively unimportant.

Principle 20: People must be protected from themselves. Since workers often neglect their own safety, each supervisor must take responsibility for certain areas of personnel and equipment safety, and particularly for unwise short-cuts and variations from the prescribed procedures.

Principle 21: Abbreviated checklists tend to cause mistakes. Checklists may be useful if the personnel are very well trained. However, less knowledgeable technicians may not go beyond the checklist when working in unfamiliar areas. Rather than refer to the detailed job procedures, they tend to experiment or fill in the gaps by guessing.

Principle 22: The equipment's reputation among users can be very important, because it may affect the way they use it and service it. Even rumors that equipment is difficult or hazardous to use can compound and magnify the basic difficulty.

Principle 23: Ease of use or maintenance affects the equipment's reliability. If items are difficult to maintain, technicians will probably not keep them in good operating condition, so they will not be ready for use when needed. If equipment is difficult to use, operators will substitute other equipment when they can.

Principle 24: Equipment is particularly susceptible to misuse if crew members must communicate with each other to use it. People seldom realize communications are inadequate until they make mistakes, and sometimes not even then.

Principle 25: In summary, the designer should remember that most safety problems in operational equipment arise not from defects in the equipment, but because people use it improperly. Realistically, we must expect that this improper use will continue in the future. Therefore designers must strive even harder to anticipate how their equipment might be misused, and to design so misuse becomes unlikely and its effects are not catastrophic. It is obviously much more effective to design to prevent misuse, rather than attempting to reduce safety hazards from manufactured equipment.